

Revision	ECO#	Approved By	Date	Revision History
B	xxxxxx	Per ECO Approvals	08/14/2012	See Last Page for Revision History

LGD LCD Module Specification for X34

13.3” (2560X1600) TFT-LCD

Revision History

Revision	Date	ECO	Author	Comments
1	09/16/11		Eric Benson	Initial Engineering Release
2	12/12/11		Eric Benson	Light Leakage and Testing Updates
3	8/8/11		Eric Benson	Optical, Mechanical, and Testing Updates
4	4/24/12		Eric Benson	Optical, Mechanical, Grinding, Electrical, Reliability Updates
5	5/28/12		Eric Benson	Optical, Electrical, Mechanical, Reliability Updates. Removed light leakage requirement
6	6/7/2012		Eric Benson	Added LCD edge ink spec.
A	8/06/2012		Eric Benson	Production Release
B	8/14/2012		Eric Benson	Added V-Com tuning requirement. Transmittance minimum updated.

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Title: ERIS, DSPL, LCD MODULE, LGD, X34	DWG Number: 069-8326	Rev. B
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1. Order Of Precedence Of Documentation Authority

In the case of any conflict in any specification related to these parts, this order of precedence of authority shall apply:

- The Purchase Order
- This Specification
- Reference Documents

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Title: ERIS, DSPL, LCD MODULE, LGD, X34	DWG Number: 069-8326	Rev. B
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2. Reference Documents

NUMBER	TITLE
069-7821	LCD, MCO, X34
070-1191	Supplier Quality and Business Requirements, Apple
070-0385	Apple Service Requirements
069-7366	LCD Engineering Cosmetic Specification
069-7370	X34 Unified Backlight Specification
080-0855	Drop, Shock and Vibration
080-0854	Four-Corner Temperature and Humidity Test
062-0087	Packaging Finished Goods Shock and Vibration
062-7993	Electromagnetic Emissions Requirements
062-7994	Electromagnetic Immunity Requirements
080-0840	EMC Production Audit Procedure
062-2082	Vendor Packaging Procedure
062-0585	FG Labeling Specification
062-2111	Manufacturing Bar Code Specification
062-2208	Static Breakage Test
070-0371	Service: Packaging Standard
070-0385	Service: Product Quality Requirements
070-1191	Supplier Quality and Business Requirement
070-1193	Barcode Label Specification
074-0321	ESD Anti-static Label Specification
13406-2.3	ISO Specification
062-0093	Apple Corporate Specification, Mandatory Requirements for Product Safety
IEC60950	Safety of Information Technology Equipment (International Standard)
EN 60950	Safety of Information Technology Equipment (European Standard based on IEC 60950)
UL 1950	Safety of Information Technology Equipment . Third Edition (US Standard based on IEC 60950) C22.2 No. 950 Safety of Information Technology Equipment. Third Edition (Canadian Standard based on IEC 60950)
UL 94	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances (UL standard for flame testing plastics. Includes test requirements for HB, V-2, V-1 and V-0 flame ratings)
JIS K 5401	Pencil Scratch Tester for Coated Film 13406-2.3
069-0279	Product Safety Requirements for Component Flat Panel Display Assemblies
069-1111	Apple RoHS Compliance Specification
080-2153	Apple's RoHS Declaration of Conformity Procedure

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3. General Description

The board assembly drawing for X34 is shown in Figure 1. The LCD Module contains the following hardware. From this point forward the complete Unified Display for X34 13.3" TFT-LCD will be referred to as the unit.

- 2x 0.3 mm glass (TFT and CF)
- Liquid Crystal
- Front and Rear Polarizers
- IC Drivers on glass
- PCB with rigid flex cables
- COG Spacer
- ITO Tape
- PCB Label / Insulation Tape

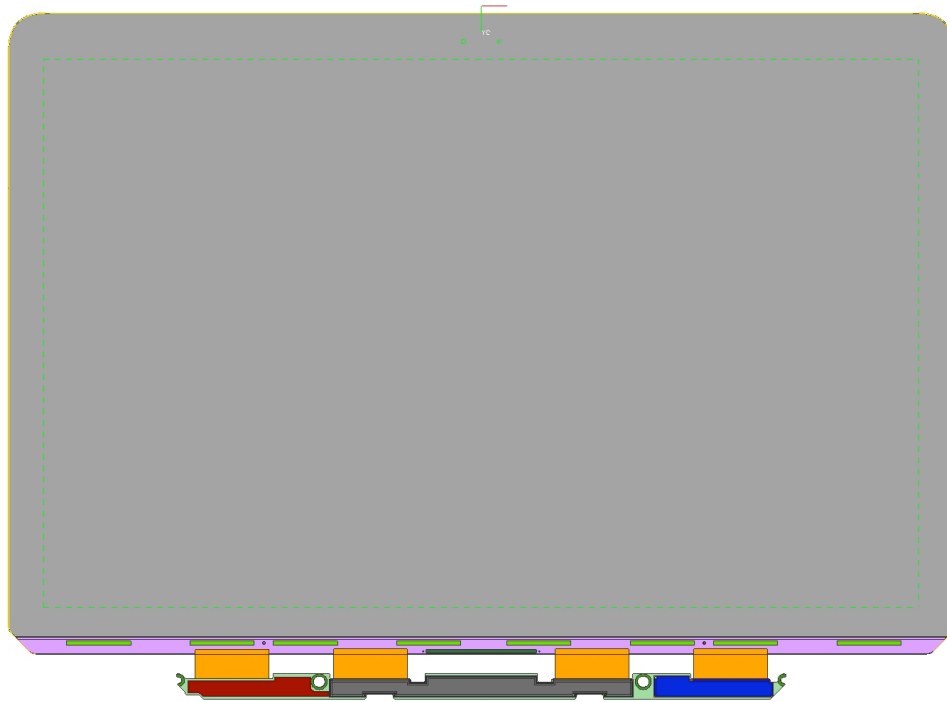


Figure 1 LCD Assembly Overview

4. Functional Requirements

Table 1 provides a summary of the functionality and requirements of the LCD Module.

Table 1 Unified Display for X34 General Description

<u>Category</u>	<u>Parameter</u>	<u>Specification</u>	<u>Reference Section</u>
General	LCD TYPE	Normally-Black Transmissive, Mobile-IPS a-SI TFT-LCD	4.1
	Product Code	TBA	N/A
	Manufacturer	LGD	N/A
	Manufacturer P/N	TBD	N/A
	Diagonal	13.3"	
	Pixel Format	2560 (RGB stripe, H) x 1600 (V)	4.4
	Pixel Pitch	0.03725(V) x 3 x 0.11175(H) mm	4.3
	Color Depth	24-bits (8R, 8G, 8B)	
	Packaging	Protective film on front & back polarizer w/ pull tab. LCD board packaged and sealed in ESD protection bags in class 10k or better clean room with all the glass edge & flex/ PCB protections	
Electrical	Interface	5V input power, 4 lane DisplayPort interface	7.4.3
	Power Consumption	2.0W Typical (Web Black/White/Mosaic) 2.6W Worse Case (R/G/B)	7.4.5
	Inversion	Z-inversion (1-dot)	4.6
	Color Filter ITO Sheet Resistance	2.0 k Ω / square typical 2.5 k Ω / square maximum	7.12
	Active Area	286.08 mm (H) X 178.80 mm (V)	5.2
Mechanical	Minimum Viewing Area	354.11 mm x 231.70 mm	
	Module Outline Size	354.49 mm x 237.30 mm	5.1
	LCD Panel Receptacle	iPEX:CAB CA 30 pins: 20525-130E-02	7.4.1
	Cable Plug	iPEX:CAB CA 30 pins: 20523-130T-01	7.4.1
	Perimeter Flatness	0.3 mm	
	Vertical Bending	-5 to 15	
	Mass	125 (typical), max 130 g	5.3
	Operating Temperature (functioning)	0°C to +60°C	9.5
Environmental	Storage Temperature	25 +/- 3 °C and 60% +/- 5% relative humidity to maintain panel flatness	

4.1. Display Model

The unit shall be Normally-Black, Transmissive, Mobile-IPS a-SI TFT-LCD with compensation film polarizer.

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4.2. Pixel Configuration

The unit shall be configured using a RGB Vertical Stripe, Vertical Chevron Dual Domain.

4.3. Pixel Pitch

The unit shall provide a sub pixel pitch no greater than 0.03725 mm x 0.11175 mm

4.4. Resolution

The unit shall be no less than 2560 (RGB stripe, H) x 1600 (V).

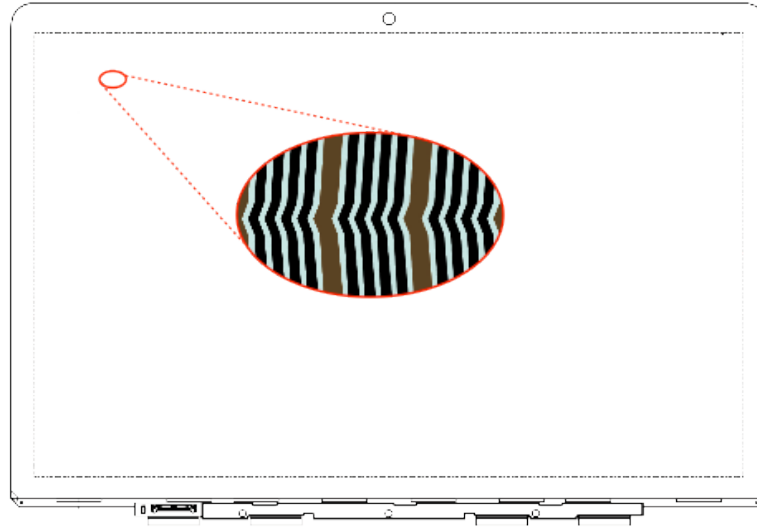


Figure 2 Resolution Overview

4.5. Rubbing Direction

The unit shall have Color Filter (CF) Rubbing from the bottom of the module to the top and shall have TFT Rubbing from the top of the module to the bottom as shown in Figure 3.

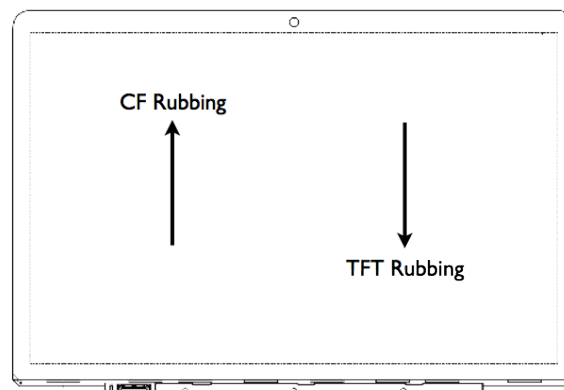


Figure 3 Rubbing Directions

4.6. Interface and Driving Scheme

The unit shall provide a 5V 4-lane DisplayPort interface, requiring Hsync and Vsync signals, along with DE (Data Enable) mode, 1-dot Z-inversion scheme.

4.7. Front Surface Treatment

The front surface of the unit shall provide a Dry AR1.5 coating that meets the requirements specified herein.

5. Mechanical Requirements

5.1. Envelope Dimensions and Tolerances

The unit shall meet the dimensional requirements specified in 069-7821 LCD, MCO, X34.

5.2. Active Area

The unit shall meet the active area requirement specified in 069-7821 LCD, MCO, X34.

5.3. Mass

The unit mass shall not exceed the mass specified in 069-7821 LCD, MCO, X34.

5.4. Unit Flatness

The LCD module shall meet the flatness requirement specified in 069-7821 LCD, MCO, X34.

5.4.1. Flatness Measurement Requirements

All units shall require a flatness measurement after aging that meet the following requirements:

- Flatness measurement shall be completed within 24 hours after removal from aging chamber
- Post aging, unit shall be stored in 25 +/- 3 °C and 60% +/- 5% relative humidity

5.5. Exposed Area and Restrictions

The display module shall not have exposed edges or components, which may cause injury or damage during handling, inspection, assembly, and service. Exposed areas of the display module (those not protected or shielded by construction) must be insulated and otherwise protected to eliminate the possibility of electrical shorting or destructive ESD discharges (per Section 7.2) during handling, inspection, assembly, and service.

5.6. Edge Quality Requirements

The edge quality of the module shall be measured using an optical profiler such as the Keyence VK-9700 or equivalent.

5.6.1. Surface Finish Requirements

5.6.1.1. Measurement Requirements

The following settings on the Keyence VK-9700 shall be used to measure the surface finish requirements.

- 20x Objective
- Measurement Area: 0.25 mm x 0.1 mm
- Measurement Area distance from Glass Grinding Transition: 0.015 mm

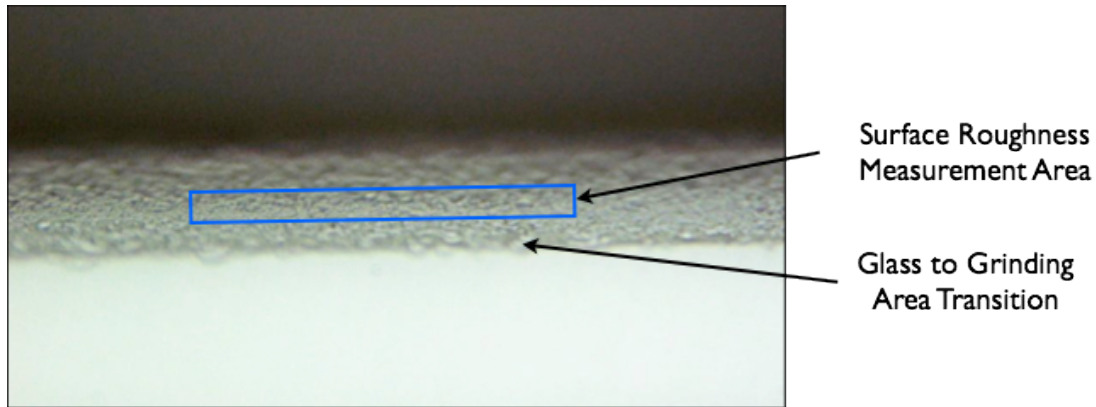


Figure 4 Surface Roughness Measurement Area

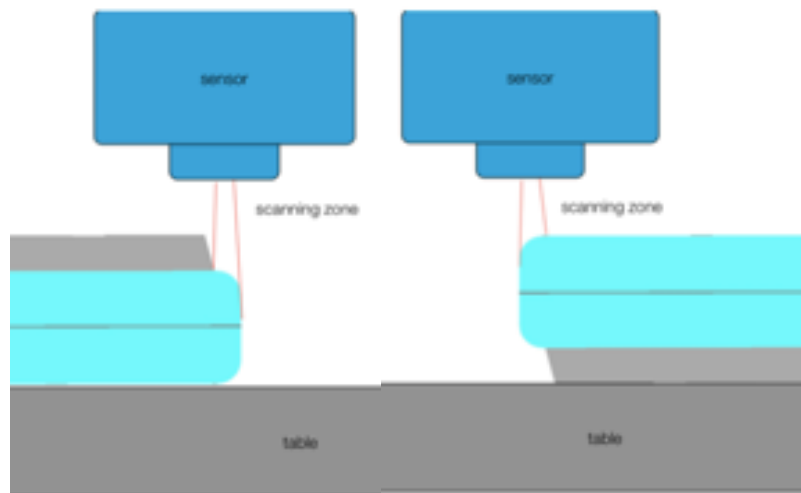


Figure 5 Surface Roughness Measurement Test Configurations

5.6.1.2. Root Mean Square (Rq)

The ground edge surface Root Mean Square shall not exceed 2.25 μm .

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Root Mean Square is defined as:

S_q	Root Mean Square Height	Standard deviation of the height distribution, or RMS surface roughness. $S_q = \sqrt{\frac{1}{A} \iint_A z^2(x,y) dx dy}$ computes the standard deviation for the amplitudes of the surface (RMS)
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5.6.1.3. Maximum Height (Rz_max)

The ground edge Maximum Height shall not exceed 25 um where maximum height is defined as distance between the highest peak and the lowest valley.

5.6.2. Edge Defect Requirements

The module shall have an edge scan completed using the Meere Company X35 EDGE INSPECTION SYSTEM Model No. EI-AGTT-17.3.

The ground edge surface shall not exceed the following chip size requirements as specified for each grinding zone (see Figure 6).

- Zone 1: CF/TFT Glass Perimeter (0.6t)
 - 0 defects greater than 50 um in any direction
- Zone 2: Bottom TFT Ledge (0.3t)
 - 0 defects greater than 50 um in any direction
- Zone 3: CF Edge (Scribe / Break)
 - X-Dimension: Defect shall not exceed 500 um
 - Y-Dimension: Defect shall not exceed 500 um
- Zone 4: Bottom TFT Corners (0.3t)
 - X- Dimension: No defect length requirement
 - Y-Dimension: Defect shall not exceed 150 um

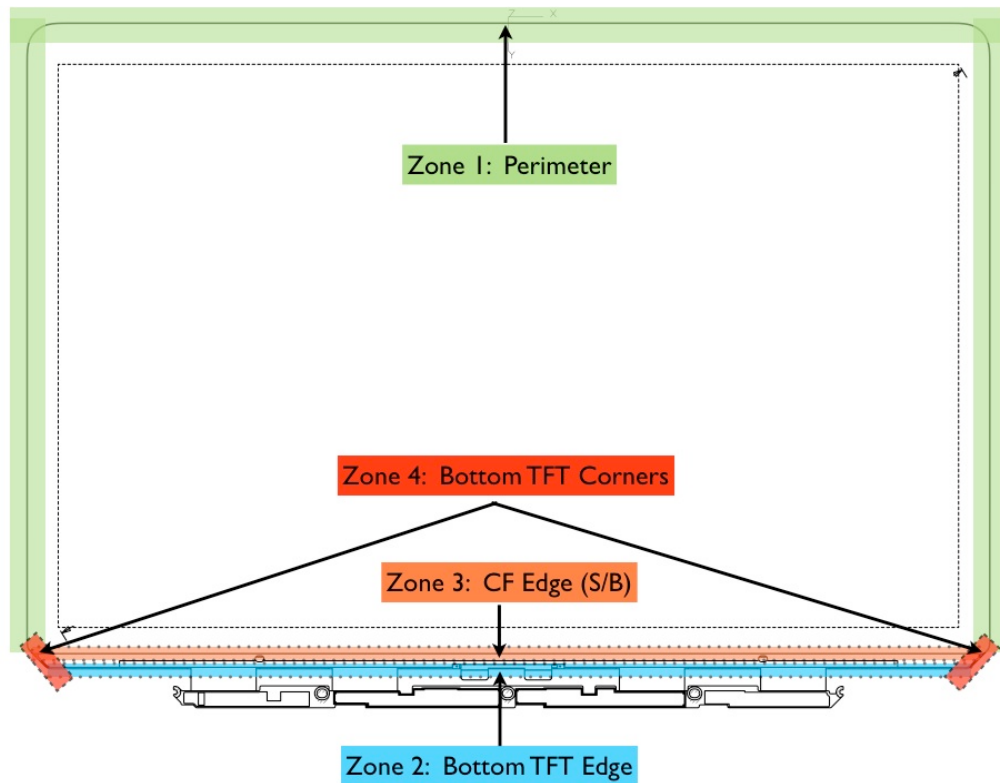


Figure 6 Grinding Zone Definitions

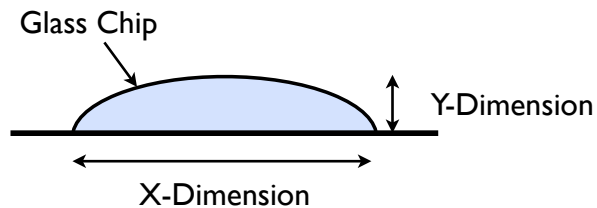


Figure 7 Glass Chip Profile Definition

5.6.3. Ground Surface Profile

The top and bottom chamfer size (Figure 8) of the glass shall meet the following requirements shown below in the specified zone (Figure 9):

- Zone 1: CF/TFT Glass Perimeter (0.6t):
 - $200\text{ }\mu\text{m} \geq \text{chamfer size} \geq 60\text{ }\mu\text{m}$
- Zone 2: Bottom TFT Ledge (0.3t)
 - $200\text{ }\mu\text{m} \geq \text{chamfer size} \geq 50\text{ }\mu\text{m}$

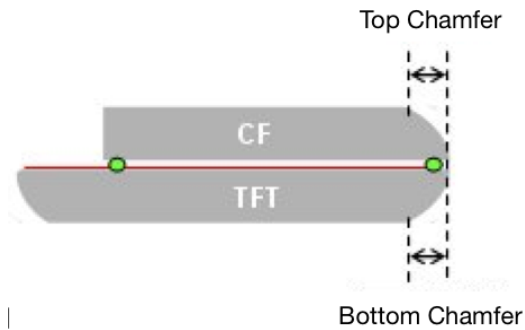


Figure 8 Chamfer of grinding edge profile

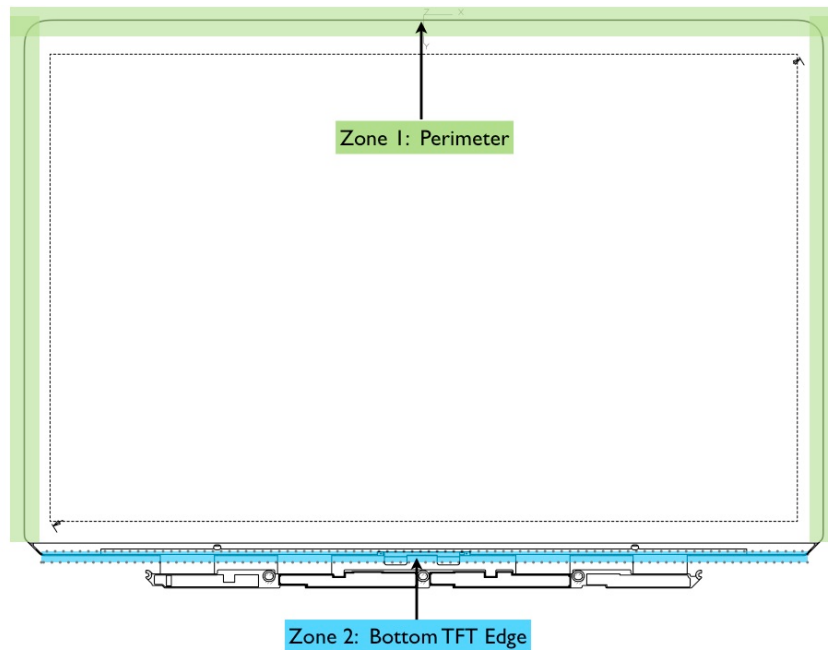


Figure 9 Grinding Profile Zone Definitions

5.7. Polarizer Edge Requirement

The laser cut polarizer edge with release lines removed shall be inspected using a variable pressure electron microscope to evaluate polarizer edge damage.

Polarizer overhang on the edge of the polarizer caused from laser cutting shall not exceed 15 um as shown in Figure 10.

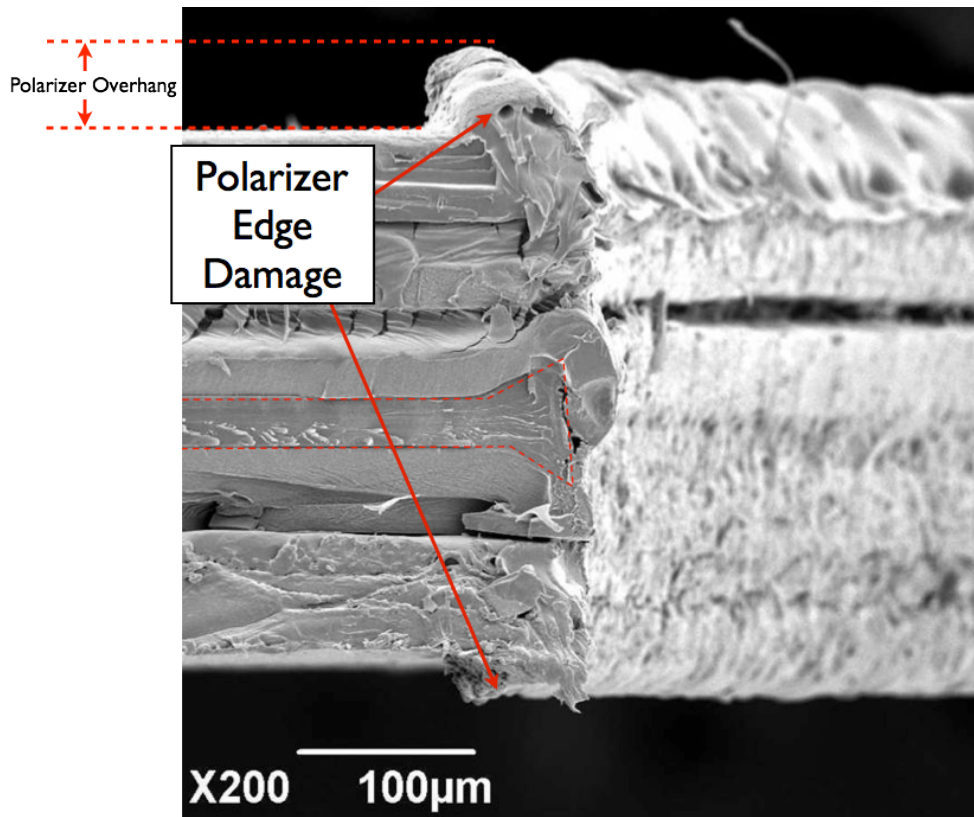


Figure 10 Polarizer Overhang Requirement

5.8. Mechanical Stack-up

The unit shall meet the stack-up requirements specified in 069-7821 LCD, MCO, X34.

Mechanical Stack-up	Part #	Nominal Thickness (mm)
Top Polarizer	Nitto Denko NATZ-AR1.5	0.166
LCD Glass CF	-	0.30
LCD Glass TFT	-	0.30
Bottom Polarizer (glossy, APCF)	Nitto Denko APCFG3CVTT	0.162
Total	-	0.928

5.9. Driver IC Mechanical Requirements

The driver IC shall meet the envelope requirements specified in 069-7821 LCD, MCO, X34.

5.9.1. Driver IC Edge Quality

The Driver IC chip depth shall not exceed 35 um on any edge as shown in Figure 11.

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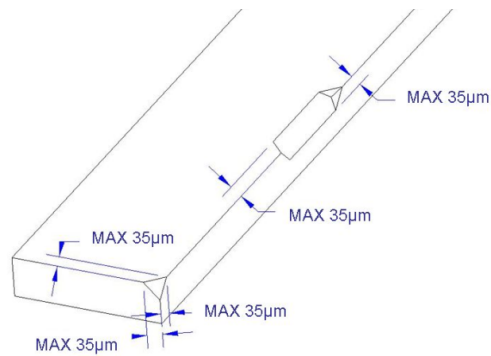


Figure 11 Driver IC Edge Quality

5.9.2. Driver IC Top Surface Requirement

The top surface of the driver IC shall meet the following requirements as defined in ASME B.46.1-1995

- $Ra \leq 0.015 \text{ um}$
- $Rmax \leq 0.100 \text{ um}$

5.10. Unit Edge Ink Requirement

A black halogen free ink approved by Apple shall be applied to the edge of the unit in the location specified in 069-7821 LCD, MCO, X34.

6. Thermal Requirements

The unit white point color shift over temperature shall meet $\Delta u'v' \leq 0.008$ from 30 °C to 50 °C.

7. Electrical Requirements

The unit shall meet the electrical requirements as specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.1. Block Diagram

The unit shall meet the interface requirements as specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

The block diagram is shown in Figure 12 as reference only.

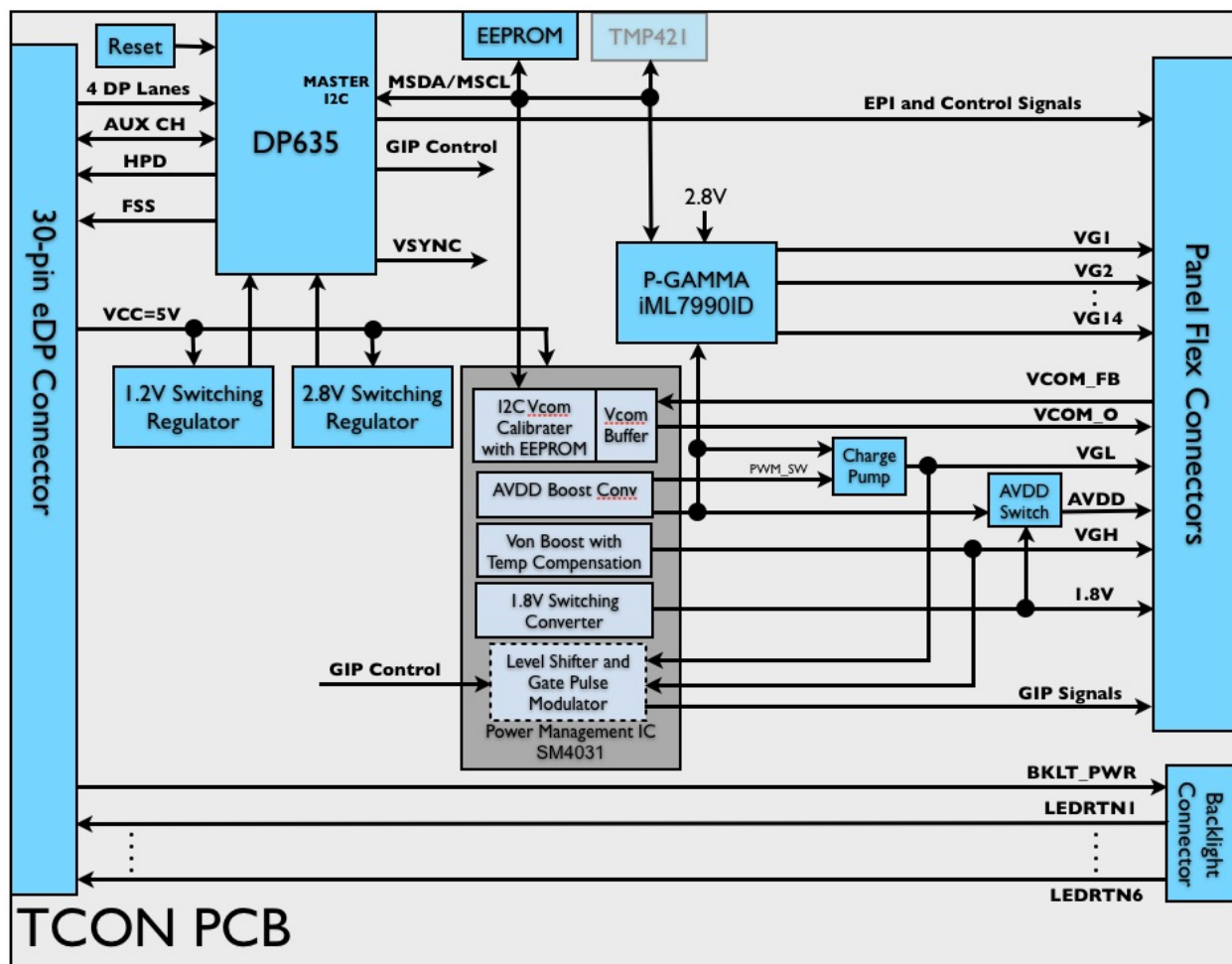


Figure 12 Unit Electrical Block Diagram (FOR REFERENCE ONLY)

7.2. Display PCB Schematics

The unit shall meet the schematic diagram as specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

- Schematics shall be provided with the following information:
- Numbered by version and date coding, PDF searchable
- Include signal-net page-number tags where signal-nets transfer to other pages
- Resistors to show the value, tolerance, and package information
- Capacitors to show the value, rating, tolerance, material, and package information
- Inductors to show the value, rating (current & power), tolerance, and package information
- Fuses to show the rating and package information.
- ICs, Diodes, Inductors, Fuses, and Connectors must show the Manufacturer, Manufacturer's Part Number, and package information.
- Test points

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7.3. Display PCB Layout

The unit shall meet PCB layout requirements specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD. .

The PCB CAD layout files shall be provided for Apple approval shall be an Allegro .brd file format. The other acceptable format is Spectra format - AutoVue compatible.

7.4. Active Components

The unit shall active components requirements as specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.4.1. Electrical Interface Requirements

7.4.1.1. Connector Requirements

The unit shall provide an IPEX 20525-130E-02 connector (1.0 mm thickness, lock-in type) as shown in Figure 13. Pin 1 on the connector is defined by the datum mark (triangle) located on the connector (see Figure 73).

Apple will provide an IPEX 20523-130T-01 mating connector (micro-coax type).

The unit connector and mating connect shall have palladium-nickel plating (silver color).

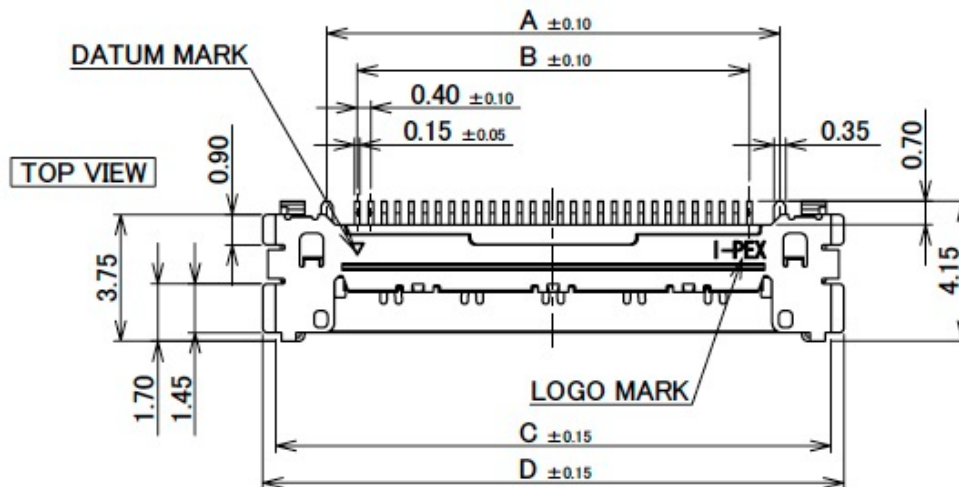


Figure 13 Connector Drawing (PCB Side)

7.4.1.2. Connector Pin Assignments

The unit shall meet connector pin assignments specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

Table 2 presents the connector pin assignments and is for reference only.

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Table 2 Display Subsystem Connector Pin Assignment (FOR REFERENCE ONLY)

Pin	Signal	Description	Cable Gauge
1	BKLT_PWR	48V	Solid AWG36
2	N.C.	Arc prevention	-
3	LEDRTN6	Backlight Return Current	uCoax AWG42
4	LEDRTN5	Backlight Return Current	uCoax AWG42
5	LEDRTN4	Backlight Return Current	uCoax AWG42
6	LEDRTN3	Backlight Return Current	uCoax AWG42
7	LEDRTN2	Backlight Return Current	uCoax AWG42
8	LEDRTN1	Backlight Return Current	uCoax AWG42
9	HPD	Hot Plug	uCoax AWG42
10	FSS	Frame Sync mux	uCoax AWG42
11	AUX_P	eDP AUX	uCoax AWG42
12	AUX_N	eDP AUX	uCoax AWG42
13	GND	Shield	-
14	DP0_P	eDP pair 0	90Ω Twin-Ax AWG40
15	DP0_N	eDP Pair 0	
16	GND	Shield	-
17	DPI_P	eDP pair 1	90Ω Twin-Ax AWG40
18	DPI_N	eDP pair 1	
19	GND	Shield	-
20	DP2_P	eDP pair 2	90Ω Twin-Ax AWG40
21	DP2_N	eDP pair 2	
22	GND	Shield	-
23	DP3_P	eDP pair 3	90Ω Twin-Ax AWG40
24	DP3_N	eDP pair 3	
25	GND	Digital Ground	Solid AWG36
26	GND	Digital Ground	Solid AWG36
27	GND	Digital Ground	Solid AWG36
28	VCC	5V	Solid AWG36
29	VCC	5V	Solid AWG36
30	VCC	5V	Solid AWG36

7.4.2. Extended Display Identification Data (EDID) Interface

The unit shall meet EDID interface requirements specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD and shown in Table 3 (for reference only).

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Table 3 EDID Data (FOR REFERENCE ONLY)

Field Name	#	Raw Hex	Interpretation
Header	0-7	0x00, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0x00	
ID Manufacturer Name	8-9	0x06, 0x10	APP
ID Product Code	10-11	0x14, 0xA0	
ID Serial Number	12-15	0x00, 0x00, 0x00, 0x00	01
Date of Manufacture	16-17	0x0A, 0x16	March 4, 2012
EDID Structure Version/Revision Number	18-19	0x01, 0x04	1.4
Video Input Definition	20	0xA5	Bit 7 = 1, Display accepts digital input Color bit depth is 8 bits per primary color DisplayPort is supported
Max Horizontal Image Size	21	0x1D	29 cm
Max Vertical Image Size	22	0x12	18 cm
Display Transfer Characteristic (Gamma)	23	0x78	2.20
Feature and DPMS Support	24	0x02	Bit 7 = 0, Display doesn't support DPMS Stand-by Bit 6 = 0, Display doesn't support DPMS Suspend Bit 5 = 0, Display doesn't support DPMS Active Off Bits [4:3] = Supported Color Encoding Formats, [0:0] = RGB 4:4:4 is supported Bit 2 = 0, Display doesn't use the sRGB standard default color space as its primary color space Bit 1 = 1, Display's preferred timing is native Bit 0 = 0, Multi-scan display
Color Characteristics	25-34	0x6F 0xB1 0xA7 0x55 0x4C 0x9E 0x25 0x0C 0x50 0x54	Red_x Value = 0.65236 Red_y Value = 0.33206 Green_x Value = 0.29692 Green_y Value = 0.61723 Blue_x Value = 0.14456 Blue_y Value = 0.04692 White_x Value = 0.31250 White_y Value = 0.32814
Established Timing 1	35	0x00	
Established Timing 2	36	0x00	

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Manufacturer's Timings	37	0x00	
Standard Timing Identification 1	38-39	0x01, 0x01	not used
Standard Timing Identification 2	40-41	0x01, 0x01	not used
Standard Timing Identification 3	42-43	0x01, 0x01	not used
Standard Timing Identification 4	44-45	0x01, 0x01	not used
Standard Timing Identification 5	46-47	0x01, 0x01	not used
Standard Timing Identification 6	48-49	0x01, 0x01	not used
Standard Timing Identification 7	50-51	0x01, 0x01	not used
Standard Timing Identification 8	52-53	0x01, 0x01	not used
Detailed Timing Description 1	54-71	0xE2 0x68 0x00 0xA0 0xA0 0x40 0x2E 0x60 0x30 0x20 0x36 0x00 0x1E 0xB3 0x10 0x00 0x00 0x1A	Pixel Clock = 268.50 MHz Horizontal Active = 2560 Pixels Horizontal Blanking = 160 Pixels Vertical Active = 1600 Lines Vertical Blanking = 46 Lines Horizontal Sync Offset (Front Porch) = 48 Pixels (from blanking start) Horizontal Sync Pulse Width = 32 Pixels Vertical Sync Offset = 3 lines Vertical Sync Pulse Width = 6 Lines Horizontal Image Size = 286 mm Vertical Image Size = 179 mm Horizontal Border = 0 Pixels Vertical Border = 0 Lines Flags: Bit 7 = 0, Non-interlaced Bit [6:5:0] = [0:0:x], Normal display (non-stereo) Bit [4:3] = [1:1], Digital Separate Syncs Bit 2 = 0, negative true VSync Bit 1 = 1, positive true HSync Calculated Horizontal Refresh = 98.71 kHz Calculated Vertical Refresh = 59.97 Hz
Monitor Description 2	72-89	0x00 0x00 0x00 0xFC 0x00 0x43 0x6F 0x6C 0x6F 0x72 0x20 0x4C 0x43 0x44	Monitor Name: Color LCD

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		0x0A 0x20 0x20 0x20	
Monitor Description 3	90- 107	0x00 0x00 0x00 0x10 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00	Dummy descriptor.
Monitor Description 4	108 - 125	0x00 0x00 0x00 0x10 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00	Dummy descriptor.
Extension Flag	126	0x00	0
Checksum	127	0x8D	141

7.4.3. Power Supply Requirements

The unit shall meet the internal power supply requirements in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.4.4. Signal Timing

7.4.4.1. Embedded DisplayPort (eDP) Signal Requirement

The unit shall meet the digital communications interface specified in VESA DisplayPort Standard, Version 1, Revision 1a and VESA Embedded DisplayPort Standard, Version 1.3.

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7.4.4.2. Display Timing Data

The unit shall meet display timing data requirements in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.4.4.3. Color Input Data Reference

The color data reference specified in Table 4 shall be used for the reference for color versus data input.

The brightness of each primary color (red, green and blue) is based on the 8-bit gray scale data input for the color. The higher the binary input, the brighter the color.

Table 4 Color Data Reference

Color		Input Color Data																							
		Red								Green								Blue							
		MSB				LSB				MSB				LSB				MSB				LSB			
		R7	R6	R5	R4	R3	R2	R1	R0	G7	G6	G5	G4	G3	G2	G1	G0	B7	B6	B5	B4	B3	B2	B1	B0
Basic Colors	Black	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(255)	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Green(255)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
	Blue(255)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
	Cyan	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Magenta	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
	Yellow	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
	White	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Red	Red(00)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dark	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(01)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(02)	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(253)	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(254)	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red(255) Bright																								
Green	Green(00)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Green(01)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Green(02)	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
	Green(253)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
	Green(254)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
	Green(255) Bright																								
Blue	Blue(00)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Blue(01)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Blue(02)	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1
	Blue(253)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
	Blue(254)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
	Blue(255) Bright																								

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7.4.5. Power Requirements (W/O backlight)

The unit (w/o backlight) shall meet the internal power requirements in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

The unit with the backlight turned off shall meet the power requirements shown in Table 7.45 using the display pattern requirements specified in 7.4.6.

Table 7.45 Power Requirements (FOR REFERENCE ONLY)

Pattern	Nominal	Max	Unit
White	380	440	mA
Mosaic	380	440	mA
Horizontal Line - One On / One Off	570	660	mA
Vertical Line – One On / One Off	600	690	mA
Red	500	580	mA
Black	380	430	mA

Note: (1) Display data pins and timing signal pins should be connected (GND = 0V);

(2) Operation conditions: $f_V = 60$ Hz, $f_{CLK} = 268.500$ MHz, $V_{cc} = 5$ V;

7.4.6. Display Pattern Requirements

The display patterns for system verification are defined below.

- White Pattern: All pixels in active area turned on at 100%
- Mosaic (checker) Pattern: Repeating pattern of 20 pixels x 20 pixels black and white areas over entire active area. White area has all pixels turned on at 100% and black area has all pixels turned off.
- Vertical Stripe Pattern: Sub-pixel vertical line alternating between power on and power off as shown in Figure 16.

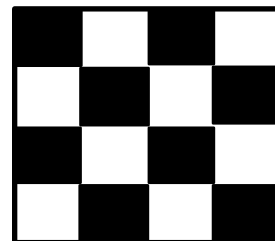
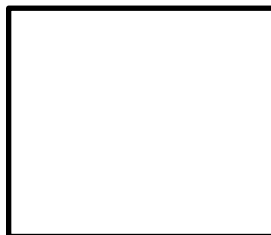


Figure 14 White Screen Display

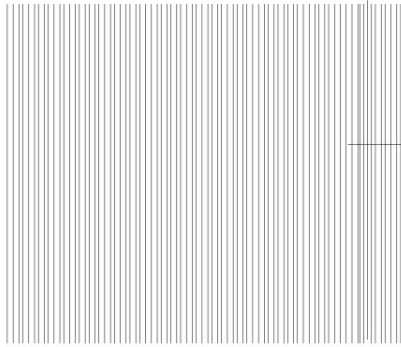


Figure 15 Mosaic Pattern Display

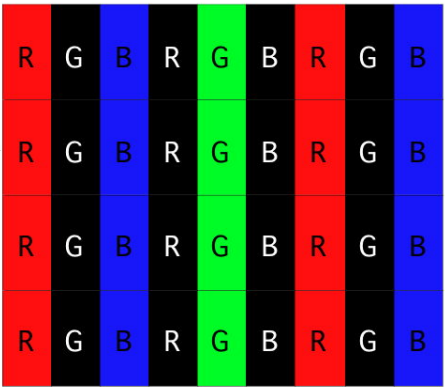


Figure 16 Vertical Stripe Pattern Display

7.5. Power on-off sequence

The unit shall meet the power on-off sequence requirements (TBD) in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.6. Vcc Voltage Drop Requirement

The unit shall operate as specified herein with a voltage drop (during power-on or normal operation) specified (TBD) in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.7. Near-Field Noise

The panel vendor shall follow the noise characterization process outlined in Apple’s near field noise spec (069-2794), and comply with noise emission limits.

Note: This spec compliance requirement is in addition to the legal EMI compliance requirements.

7.8. eDP Bit-Error-Rate (BER) Requirement

The unit shall meet the eDP Bit-Error rate requirements in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.9. COG Bit Error Rate (BER) Requirement

The unit COG chips shall meet the BER requirement in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD

7.10. Programmable Gamma Settings

The programmable gamma settings for the unit are specified in 069-8336, X34 Display TCON PCBA Engineering Requirements Specification (ERS), LGD.

7.11. Backlight Subsystem

7.11.1. General Information

Table 5 LED Requirements (Characterized at 20 mA)

LED Manufacturer	TG
LED Manufacturer Assembly P/N	E1S72-YW1L7-0F or Apple approved equivalent
Number of LEDs	42
LED Vf Ranks	5.3-5.5V, 5.5-5.7V
LED Forward Voltage Range for All 6 LED Series Lines	MAX: 42 V (Characterized at Connector for 23 mA)
LED Forward Voltage Difference between Strings	0.6V

7.11.2. Backlight Electrical Characteristics

7.11.2.1. LED controller

The unit shall drive the LED subsystem shown in Figure 17, Figure 18, and Figure 19

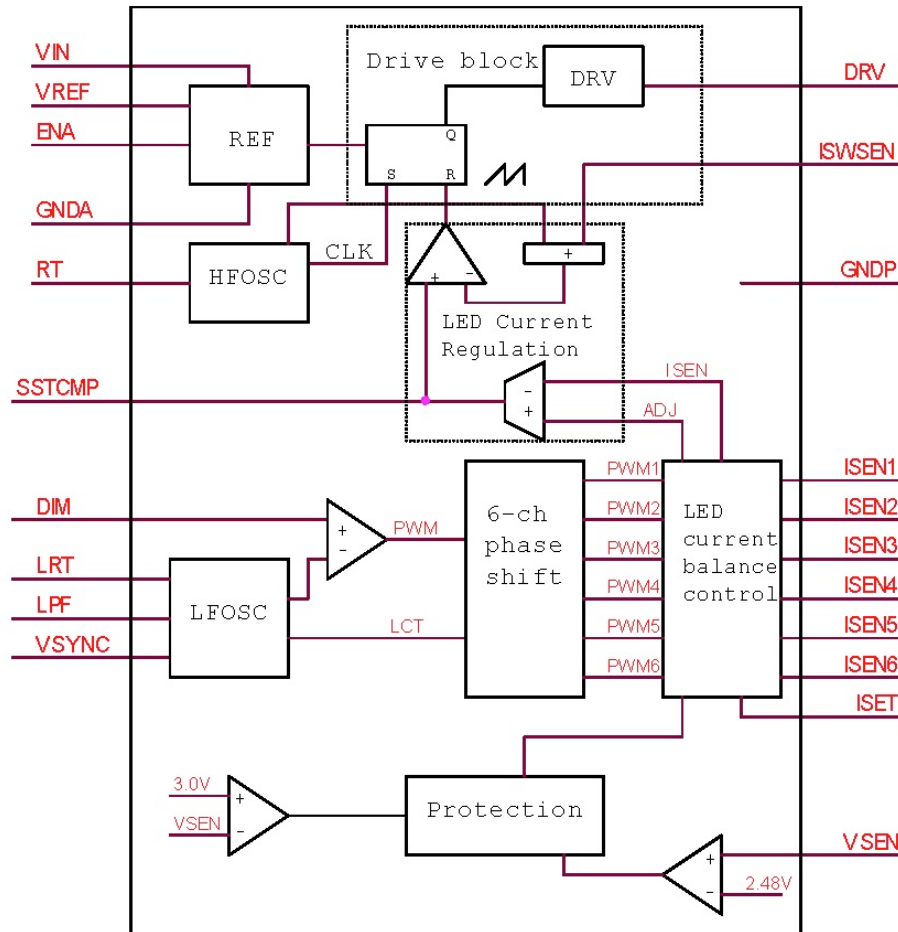


Figure 17 LED Controller Block Diagram

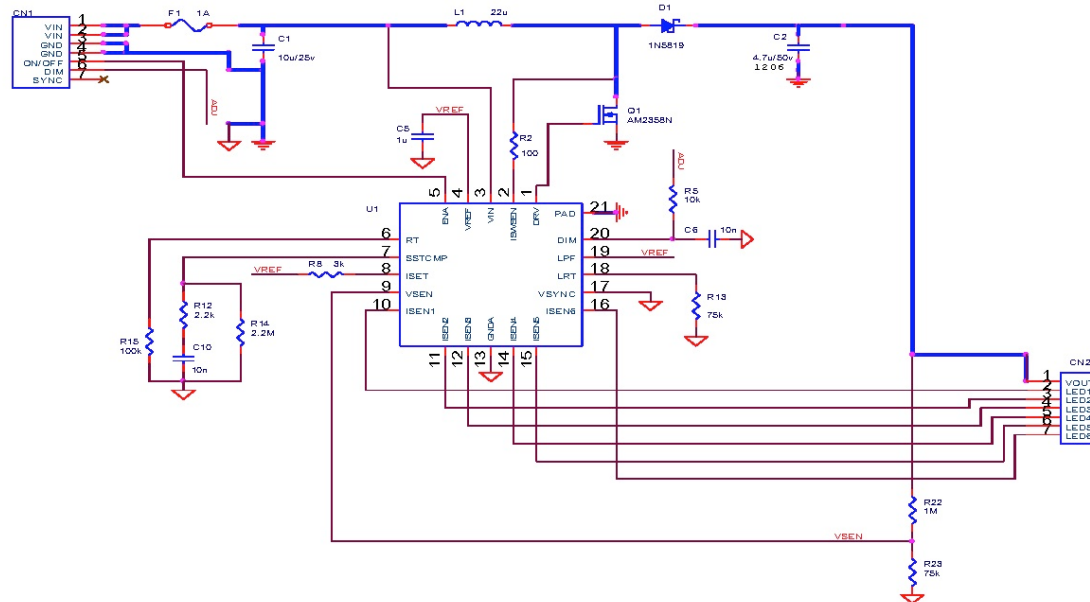


Figure 18 LED Controller Reference Application Circuits

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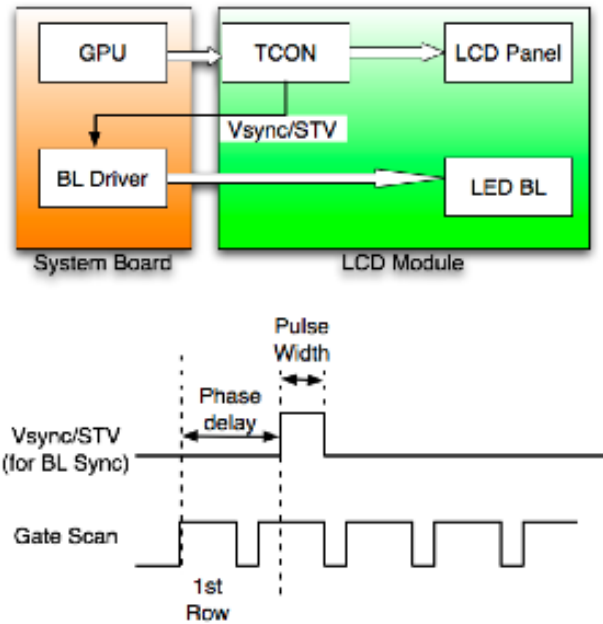


Figure 19 Display Backlight Control Diagram

7.11.3. LED Connection

The display subsystem shall have a LED connection scheme as specified in Table 6.

Table 6 LED Connection Data

String	1	2	3	4	5	6	7
1	1	7	13	19	25	31	37
2	2	8	14	20	26	32	38
3	3	9	15	21	27	33	39
4	4	10	16	22	28	34	40
5	5	11	17	23	29	35	41
6	6	12	18	24	30	36	42

Table 7 LED Connector Assignments (FOR REFERENCE ONLY)

Pin	Symbol	Description
1	NC	NC
2	LEDRTN1	Backlight Return Current
3	NC	NC
4	LEDRTN2	Backlight Return Current

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5	NC	NC
6	LEDRTN3	Backlight Return Current
7	NC	NC
8	LEDRTN4	Backlight Return Current
9	BKLT_PWR	Backlight Power (48V)
10	LEDRTN5	Backlight Return Current
11	BKLT_PWR	Backlight Power (48V)
12	LEDRTN6	Backlight Return Current

7.11.4. LED string to string current variation

LED current variation from string to string is defined as $\otimes = (I_{\max} - I_{\min})/I_{\text{avg}}$, where $I_{\max}$ and $I_{\min}$ are the maximum and minimum current on any of the 6 strings, respectively.

LED current variation $\otimes$ should be within $\pm 2.0\%$ during the complete range of PWM dimming from 20mA (100% duty) to 0.4mA (2% duty)

7.11.5. LED Driver Requirement

16-bit dimming control through Pulse Width Modulation (PWM) scheme with consistent current on LED strings. The LED string PWM signal frequency is 8KHz or higher. Between each string a 60 degree phase delay is implemented.

7.12. ITO Electrical Shielding

A transparent ITO layer shall be applied on the top surface of the CF Glass for electrical shielding that meet the electrical requirements specified in Table 8 and Figure 20.

Table 8 ITO Layer Characteristics

	Minimum	Typical	Maximum
ITO Sheet Resistance	-	2000 Ω /square	2500 Ω /square
Grounding Method	Black conductive tape connecting ITO on Color Filter Surface to ground		
Module level ITO transmittance (with polarizer)	98%	99%	-
Module level ITO white point shift (delta x & delta y)	-	-	0.001

$$\text{Tr}\% = \text{Tr}(2) / \text{Tr}(1)$$

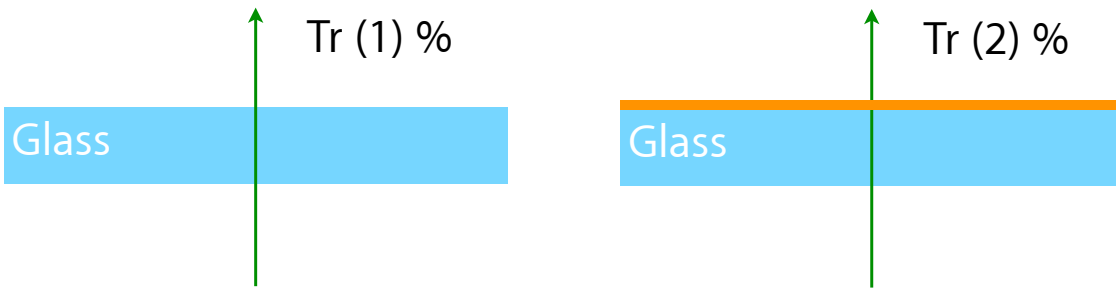


Figure 20 ITO Transmittance

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8. Optical Requirements

8.1. General Optical Specifications

The optical performance will be approved by Apple based on supplier's measurement data, visual inspection of the samples, verification measurements, and specification correlation.

Table 9 General Optical Characteristics

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit	Note	Spec
Iso-Contrast Viewing Angle	\	CR $\geq$ 100 Horizontal and Vertical Directions	75	85	--	°	1,2,3	8.15
		CR $\geq$ 10 Horizontal and Vertical Directions	85	89		°		
		CR $\geq$ 100 @ any other angle	35	40	--	°		
No Gray Inversion Angle	\	Any Angle	90	-	--	°	1,2,3	8.16
Contrast ratio	CR	Optimal	750	900	--	--	1,2,3	8.7
Color Shift	du'v'	White (255/255)	--	--	0.02	--	1,2,3	
	du'v'	Gray (127/255)	--	--	0.03	--	1,2,3	
Transmittance	T	with standard BLU	3.75	4.0	--	%	1,2,4,5	
White Chromaticity	Wx	CIE 1931	0.298	0.313	0.328	--	1,2,3,5	8.14
	Wy		0.314	0.329	0.344	--	1,2,3,5	
Red Chromaticity	Rx	CIE 1931	0.625	0.640	0.655	--	1,2,3,5	
	Ry		0.320	0.330	0.340	--	1,2,3,5	
Green Chromaticity	Gx	CIE 1931	0.285	0.300	0.315	--	1,2,3,5	
	Gy		0.580	0.600	0.620	--	1,2,3,5	
Blue Chromaticity	Bx	CIE 1931	0.140	0.150	0.160	--	1,2,3,5	
	By		0.050	0.060	0.070	--	1,2,3,5	
Black Chromaticity		No visible hue on black screen						
Blue Shift Over Temperature	$\Delta u'v'$	30 °C to 50 °C			0.008		1,2,3,5	
Max color difference over a cell	du'v'	white	--	--	0.0055	--	1,2	8.11
Max color difference w.r.t. Center	du'v'	white	--	--	0.0045	--	1,2	8.10

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Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit	Note	Spec
Max color difference between neighbors	du'v'	white	--	--	0.0022	--	1,2	8.13
Gamma	©	--	--	2.25	--	--	1,2,3	
Flicker	F	No Visual Flicker	--	--	-60	dB	1,2,3	8.21
Cross Talk	DSHA	No Visible cross-talk	--	--	1.0	%	1,2,3	8.22
Response (rise + fall time)	on+off	$\lambda = 0^\circ$, Ta=30°C	--	20	30	ms	1,2,3	8.17
Gray to Gray Response time	G2G	$\lambda = 0^\circ$, Ta=30°C	--	17	20	ms	1,2,3	8.19
Surface Reflection	R	D65 Light		1.7	1.85	%		8.6
AA Reflection Color	a*	D65 Light	-2	1	4			
	b*		5	8.5	12			

Note 1: The testing conditions are specified in 6.2.

Note 2: The definitions of optical characteristics are shown in 6.3.

Note 3: Measured at center point. Equivalent performance over the entire panel required.

Note 4: Both center point and average of 160 points.

Note 5: Test with standard BLU.

Note 6: Color measurements shall meet CpK 1.0

Note 7: Color uniformity measurement shall be done with single point light source (see Sec. 8.2.5)

8.2. Optical Measuring Conditions

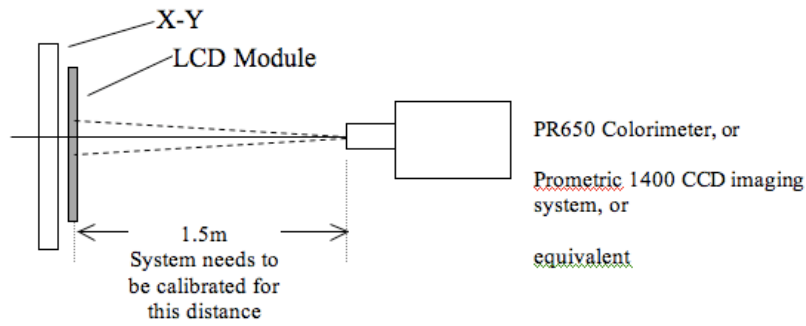
The optical characteristics are determined after the unit has been done with aging chamber at the maximum brightness, in a dark environment at an ambient temperature at $25^\circ\text{C} \pm 2^\circ\text{C}$. The electrical conditions include $V_{cc} = 5.0\text{ V}$, $f_v = 60\text{ Hz}$, $f_{CLK} = 268.50\text{ MHz}$, $I_{LED} = 23.0\text{ mA}$ at 100% duty cycle. Recommended measuring equipment for luminance and color is Photo Research PR650 Colorimeter or similar. The measuring distance should be about 150 cm from the LCD surface at normal unless otherwise specified. The (virtual) measuring spot should be 5mm in diameter. The CIE 1931 and 1967 Standards shall be used. Measurements should be done on the 160 grid points as shown in the following figures. Viewing angle measurements should be done by an Eldim EZ Color system or similar. Measurement data needs to be calibrated to Apple's equipment measurement results.

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Brightness & Color Measurement



Viewing Angle Measurement

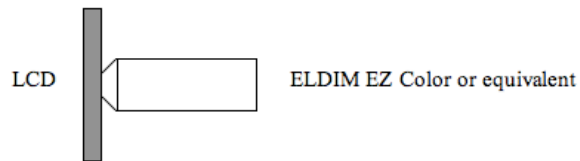


Figure 21 Optical Measurement Set-up

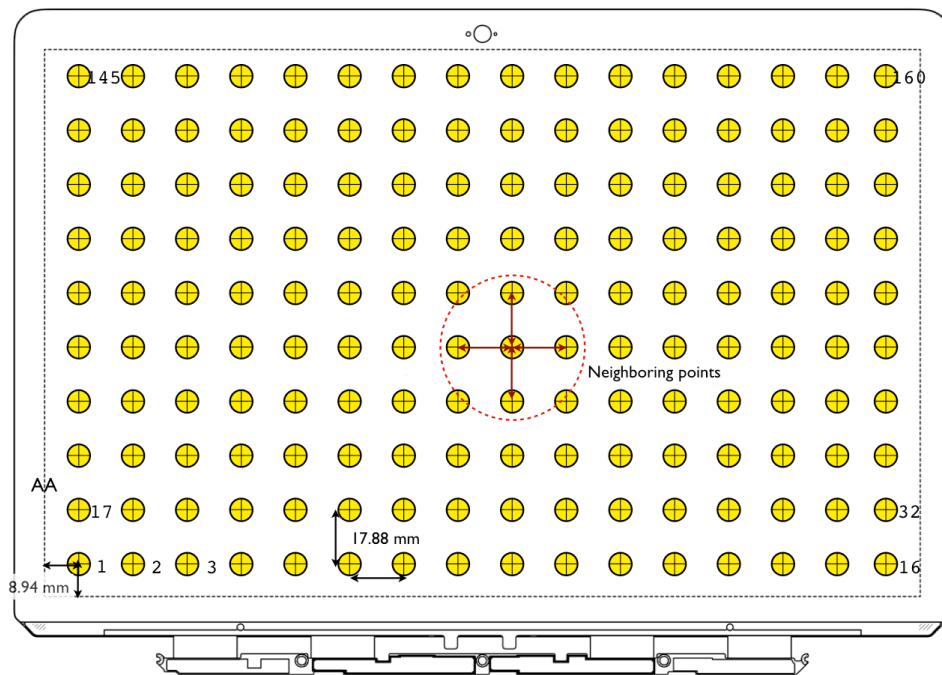


Figure 22 Optical Measurement Points

8.2.1. Center Point Luminance

L_{ct} = Average luminance at point #72, 73, 88, 89 point of the display

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8.2.2. Average Luminance

$$L_{Ave} = \text{SUM}(L_1:L_{160}) / 160$$

where L_1 to L_{160} are the luminance values measured at point #1 to #160.

8.2.3. Brightness Uniformity

No visible brighter or darker bandings, or any kind of shapes objects on the screen will be allowed. Apple requires two kinds of data for brightness uniformity: Luminance Uniformity, and Worst Neighbor Luminance Uniformity. The definitions are shown in below:

Global Luminance Uniformity:

- $U_L = 100\% - (L_{\max} - L_{\min}) / L_{\max}$
- $L_{\max} = \max \{\text{Luminance values at 160 points}\}$,
- $L_{\min} = \min \{\text{Luminance values at 160 points}\}$
- Worst Neighbor Luminance Uniformity (The 4 points that are closest to the test point)
- $WNU_L = 100\% - \text{Max}(\otimes L_1, \otimes L_2, \otimes L_3, \otimes L_4) / L_0$
- Global WNU = $\min (WNU_1, \dots WNU_{160})$

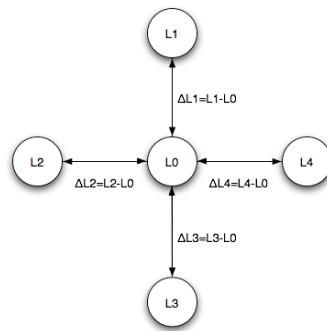


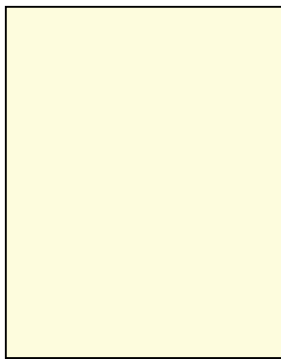
Figure 23 Neighboring points

8.2.4. Contrast Ratio

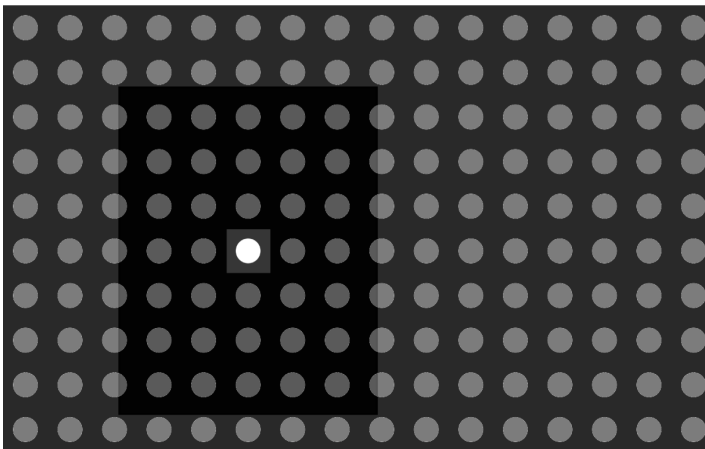
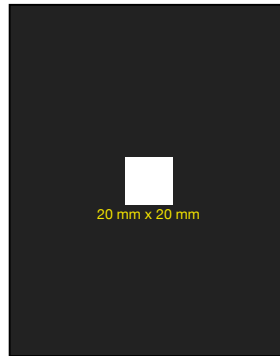
CR = Luminance at White / Luminance at Black.

8.2.5. White Color Uniformity

The entire display active area shall be scanned with the color coordinate measurement with white screen set full brightness. A point light source with standard backlight can be prepared. The color uniformity of whole cell shall be measured with scanning method on the point light source.



select a white LED backlight with good luminance and color uniformity (>80% in luminance and <0.005 overall color).



8.2.6. Panel to Panel White Color Uniformity

The center point (as defined by the average value at point #72, 73, 88, 89) white color coordinate of any panel shall be within the box with 4 corners coordination boundary listed in Table 6.1.

8.2.7. Max Color Difference with respect to the center within a panel

On each panel, the maximum color difference between any of the 160 points and the center point (defined as the average value at point #72, 73, 88, 89), represented in delta u^*v^* .

8.2.8. Max Color Difference between any two points within the panel

On each panel, the maximum color difference between any two of the 160 points, represented in delta u^*v^* .

8.2.9. Average Color Difference between top and bottom

On each backlight, the average color difference between top and bottom is calculated as

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$$u'_t = \sum_{i=1}^{16} u'_i / 16, v'_t = \sum_{i=1}^{16} v'_i / 16$$

$$u'_b = \sum_{i=145}^{160} u'_i / 16, v'_b = \sum_{i=145}^{160} v'_i / 16$$

$$\Delta u'v' = \sqrt{(u'_t - u'_b)^2 + (v'_t - v'_b)^2}$$

8.2.10. Max Color Difference between two neighbors

On each panel, the maximum color difference between any two neighboring points on the panel, represented in delta u'v'

8.2.11. RGB Color Chromaticity

The entire display active area shall be scanned with the color coordinate measurement with screen set to full brightness and solid R, G, B color respectively. The measured color coordinate of any panel shall be within the box with 4 corners coordination boundary listed in Table 6.1.

8.2.12. Viewing Angle

The viewing angle is defined as the viewing angle range under the condition at CR $\geq$ 10:1.

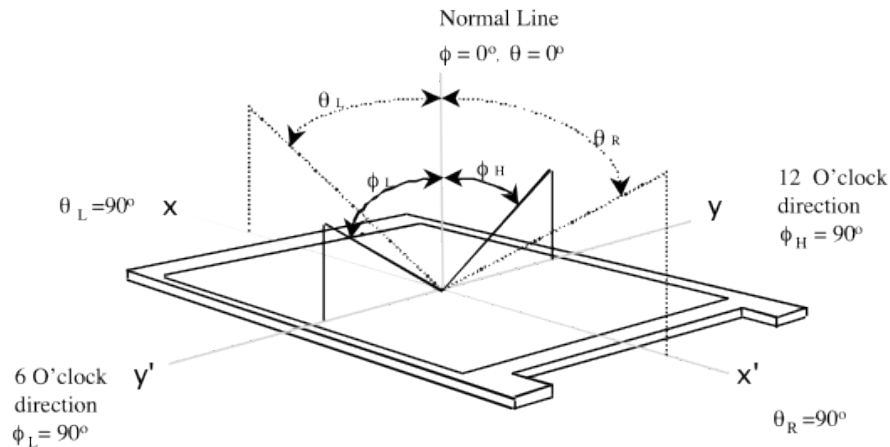


Figure 24 Viewing angle definition

8.2.13. Gray Scale Inversion

Luminance vs. viewing angle curves are measured based on gray level 255, 223, 191, 159, 127, 95, 63, 32 and 0, in the viewing angle of left, right, up, down, with PCB on the bottom side. Gray scale inversion happens when a higher gray scale measures the same luminance or lower luminance than any of the lower gray scale.

8.2.14. Response Time

8.2.14.1. On and Off Response Time

The On/Off response time, $t_R + t_F$, is defined in the following figure and shall be measured by switching the input signal for “black” and “white”.

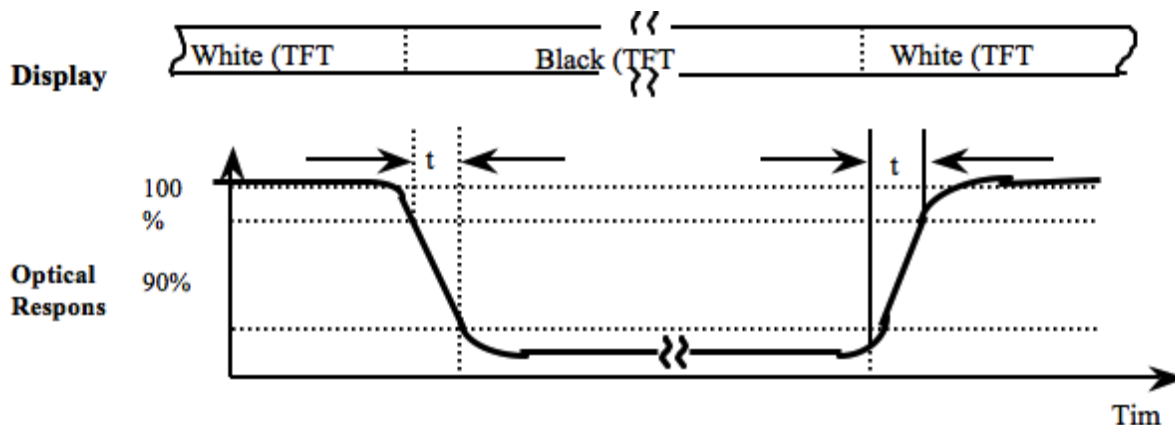


Figure 25 Response Time Measurement

8.2.14.2. Gray to Gray Response Time

Gray to Gray Response Time is measured in a similar method. But instead of switching display between black and white, panel is switched between two gray scales. The maximum gray-to-gray response time is based on 9 levels of gray scales. The 9 levels are: gray level 255, 223, 191, 159, 127, 95, 63, 32 and 0. Figure 6-6 shows an example of Gray to Gray Response Time measurement data.

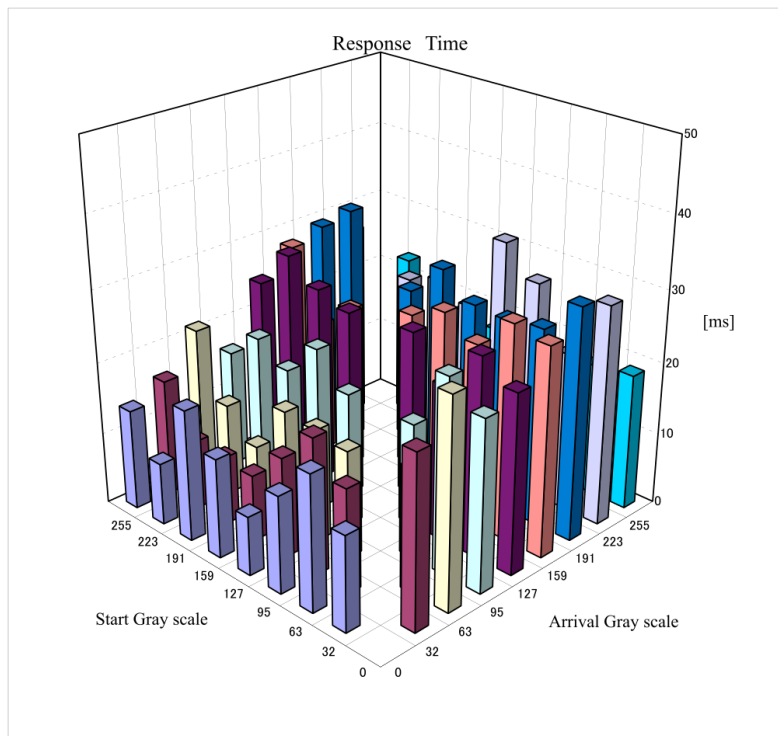


Figure 26 Gray to Gray Response Time

8.2.15. Gray Scale Linearity or Gamma Value

The display luminance, L_G , is measured at the different gray scales, $G_{\min}$, ..., $G_{\max}$. The exponential fitting is used to determine the gamma (γ) value, which should be an intrinsic or uncorrected characteristic.

$$L_G \sim G^\gamma.$$

8.3. Flicker

The unit shall not have any visual flicker and shall not exceed -60 dB as calculated from the following equation.

$$F = 10 \text{ Log } (P_x / P_0).$$

The flicker level should be measured with gray level patterns. The output signal of a photometer is sent to an FFT analyzer. The flicker is a ratio of the powers in the frequency spectrum at 30 Hz (P_x) and 0 Hz (P_0), *i.e.*,

8.4. Cross-talk

The unit shall not have any visual cross talk. Cross-talk, D_{SHA} , is defined by the following equation.

$$D_{SHA} = (LB - LA) / LB \cdot 100\%,$$

$$LA = \text{Luminance in Pattern A}$$

LB = Luminance in Pattern B.

Two luminance values are measured at center spot with 50 x 50 pixels.

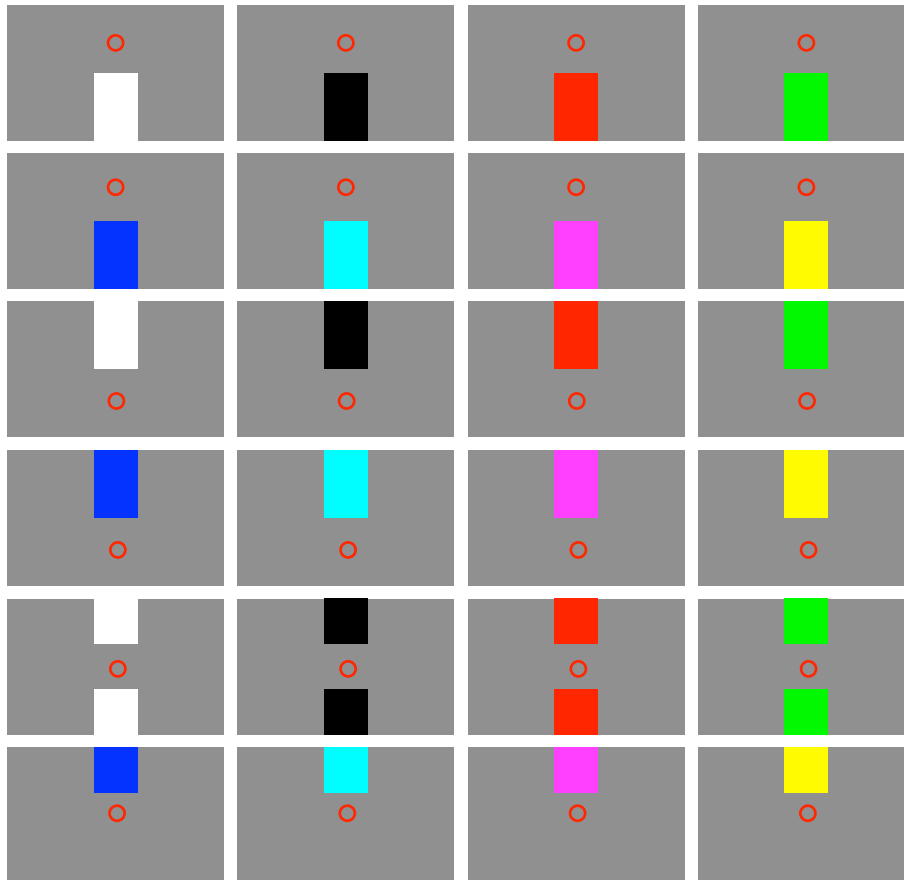


Figure 27 Cross Talk Measurement

8.5. Surface Reflection

Surface reflection measurement shall be measured with D65 light source and the incident angle is 10°. The measurement setup is illustrated in Figure 88. The LCD is with proper ITO coating and front polarizer laminated. Both black matrix and active area are needed to be characterized.

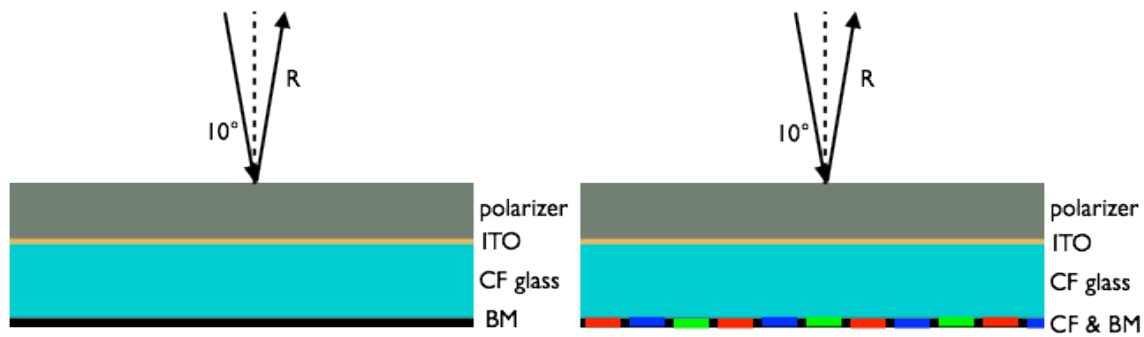


Figure 28 Surface Reflection Measurement

8.6. General Requirement for Camera and CIL/ALS Area

Table 10 Camera and CIL/ALS Requirements

	Spec Item	Value	Note
Camera Window	Transmittance	4.0dB±0.1dB	
	Parallelism	<25 arc seconds	
	Transmitted wavefront	OPD<λ/2	
	Water/oil mark and stain	Not allowed	
	Total dig, scratch, dust and white spots	<20 um	
	Air bubbles	Not allowed	
	Haze	0.3% max	
	Color shift (Typ., transmitted) a*	-1.8	
	Color shift (Typ., transmitted) b*	4.5	
	Color shift max variation Δa*	0.5	
	Color shift max variation Δb*	0.5	
ALS	Transmittance	16.8dB±0.1dB	
CIL	Transmittance	15.2dB±0.1dB	

8.7. Camera/ALS/CIL Optical Parameter Definition

8.7.1. Camera Window Transmittance

Camera window transmittance is the fraction of light transmittance through window area. The LCD shall be with proper ITO thicker coated and front polarizer laminated. The light source is D65 white light.

8.7.2. Camera Window Parallelism

Parallelism is also called wedge, which is a measure of how parallel are the polarizer surface vs rear TFT glass surface. It can be determined by interferometry of polarizer reflected and TFT glass reflected wavefront.

8.7.3. Camera Window Transmitted Wavefront Distortion

Transmitted wavefront distortion (TWD) is a measure of phase distortion, which usually influenced by surface roughness and inhomogeneous refractive index of optical medium. TWD shall be measured with a He-Ne laser ($\lambda=632.8$ nm) interferometer associated with a reference plane with distortion less than $\lambda/20$. The transmitted wavefront and reflected wavefront from reference plane is combined into interferometer. The fringe pattern from interferometry is used to determine the TWD. One fringe is correspondent to one half wavelength distortion.

8.7.4. Haze

Haze is a measure of light scattering by an inhomogeneous medium. It can be measured by BYK haze-gard plus or equivalent.

8.7.5. Color Shift

Color shift is determined with D65 light source and the color shift is measured with $L^*a^*b^*$ standard.

8.7.6. ALS and CIL Transmittance

ALS and CIL transmittance shall be measured by X-Rite OD meter. Since the collection lens and illumination area of OD meter is larger than the diameter of ALS and CIL pattern. A 0.8 mm thick steel plate with 1.6 mm opening has to be used for calibration. The measurement method and principle are illustrated in Figure 89. The transmittance of ALS and CIL pattern can be calculated by the OD value measured

- $OD_{ALS} = \log(I_1/I_2) = OD_2 - OD_1$
- $OD_{CIL} = \log(1.2 \times 1.2 / 1.6 \times 1.6) + \log(I_1/I_2) = OD_2 - OD_1 - 2.5dB$

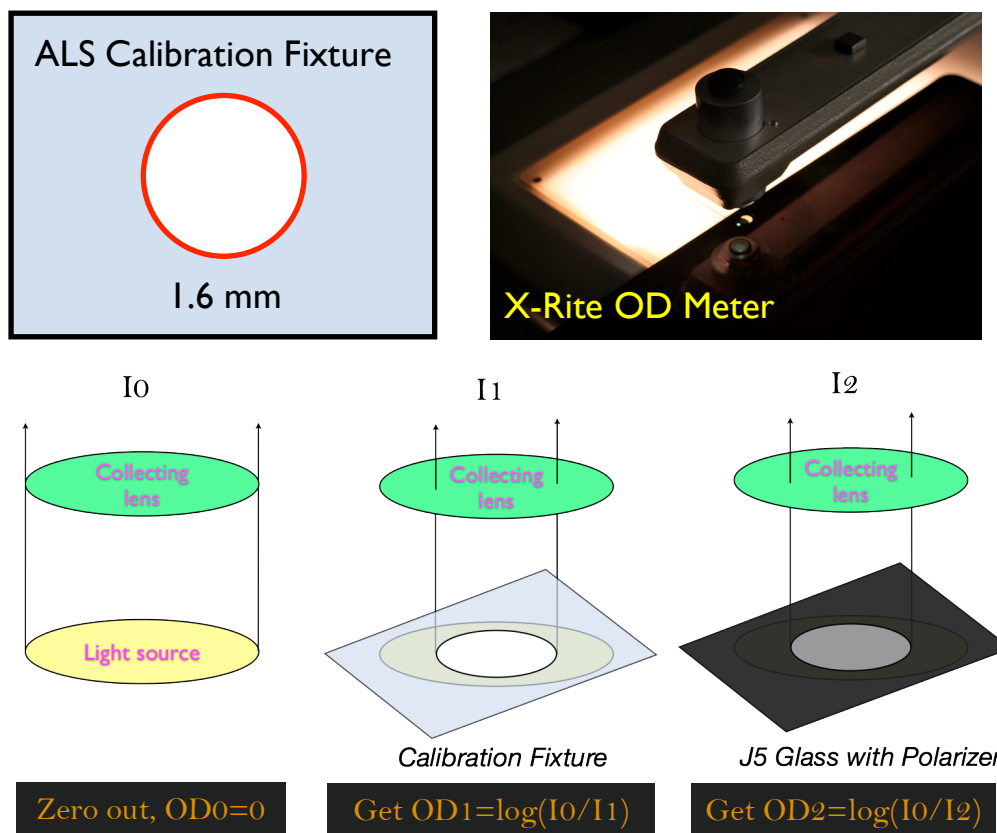


Figure 29 Camera/ALS/CIL pattern measurement

8.8. Image Retention

The unit shall meet the quick check, short term, middle term, and long term image retention requirements specified below.

The image retention test should be conducted with ~500 lux ambient illumination, 30-50cm viewing distance, at 90 degree viewing angle. Test should be conducted at 45°C, with 23mA, 5mA, and 0.4mA LED current, or equivalent PWM duty cycle.

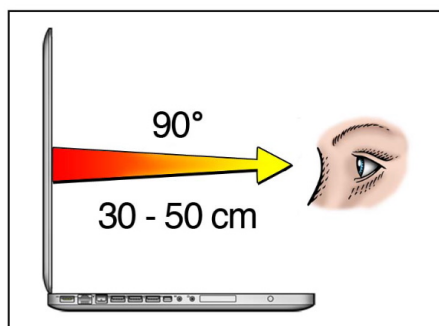


Figure 30 Image Retention Checking Condition

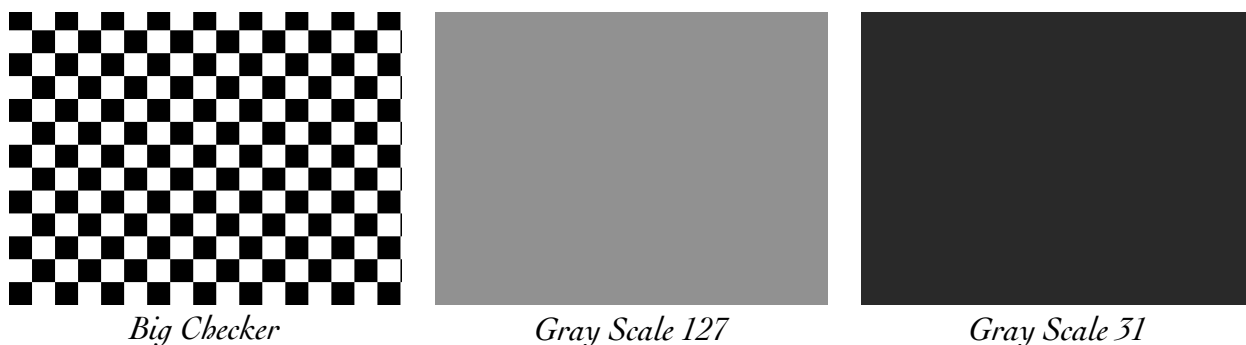


Figure 31 Image Retention Checking Patterns

8.8.1. Quick Check Image Retention

The residual pattern on the unit shall disappear in < 1 second on a uniform background of a gray scale 31.

The unit shall start from 30°C and immediately after turning on the unit display the checker pattern for 10 seconds.

8.8.2. Short Term Image Retention

The residual pattern on the unit shall disappear in < 1 minutes on a uniform background of a gray scale 31.

The unit shall start from 30°C and immediately after turning on the unit display the checker pattern for 3 minutes.

8.8.3. Middle Term

The residual pattern on the unit shall disappear in < 10 seconds on a uniform background of a gray scale 127.

The unit shall start from 30°C and immediately after turning on the unit display the checker pattern for 60 minutes.

8.8.4. Long Term

The residual pattern on the unit shall disappear in < 10 minutes on a uniform background of a gray scale 127.

The unit shall start from 30°C and immediately after turning on the unit display the checker pattern for 6 hours.

8.9. Common Voltage (Vcom) Tuning Requirements

The module Vcom level shall be tuned using the following requirements to meet the image retention requirements specified in Section 8.8.

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The optimized Vcom setting is defined as the Vcom value obtained by minimizing the flicker level using flicker meter CA210 or equivalent.

Vcom Tuning Requirements:

- Center Vcom setting shall have a -2 steps offset based on image retention margin.
- Vcom tuning accuracy shall be within ± 4 steps with respect to center Vcom setting.
- To avoid transient flicker effect, panel shall be warmed up at least 1 min before doing Vcom tuning. Longer dwell time can be applied as needed.

8.10. Color Washout

8.10.1. Testing Method and Condition

The cell shall be installed with Apple designed backlight fixture and the unit shall be ‘ON’ and stable at the maximum brightness, in a dark environment with no ambient light, and temperature at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The electrical conditions include $V_{cc} = 5.0\text{ V}$, $f_v = 60\text{ Hz}$, $f_{CLK} = 268.50\text{ MHz}$, $I_{LED} = 23.0\text{ mA}$ at 100% duty cycle. A force is applied on the cell at the location specified in Figure 32 and details of condition are listed in Table 11.

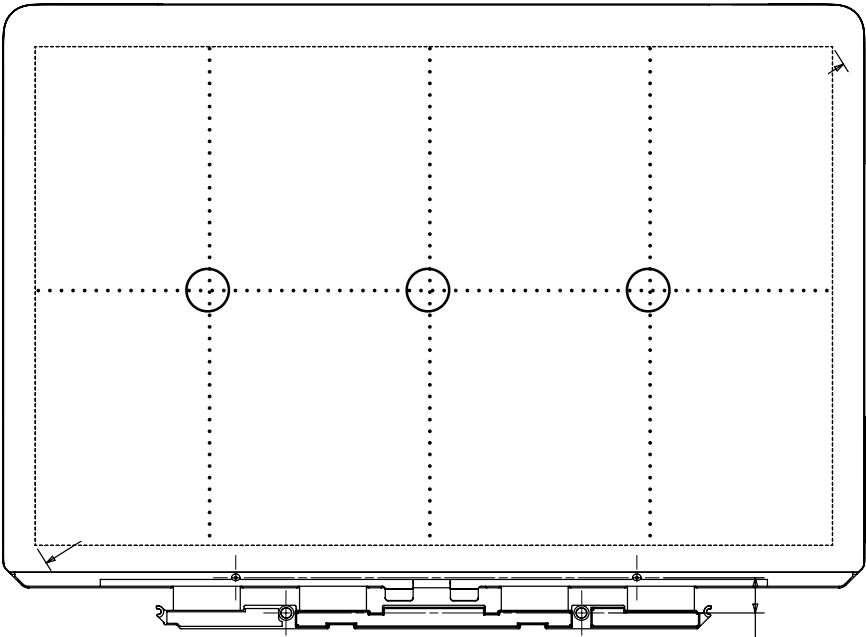


Figure 32 Color Washout Test Locations

Table 11 Color Washout Test Conditions

Parameter	Specification
Down speed	1000 mm/min

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Parameter		Specification
Load		1000 gF
Hold Time		1 sec
Up speed		1000 mm/min
Rubber Tip	Diameter	0.25"
	Hardness	70 (Durometer)

8.10.2. Observation and Pass Criteria

Operator shall check color R, G, B at full gray scale. Panel shall not show any of color washout at any azimuthal orientation after the force is released.

8.11. ODF Fill Amount and Suction Cup Testing

The unit shall have optimized ODF amount. The unit shall have suction cup test threshold pressure minimum 600 mbar using an Apple approved suction cut test fixture.

The test shall be performed with 128 gray and high vacuum is applied on panel center to generate yellow spot locally. The threshold pressure is defined as minimum pressure to allow yellow spot disappear.

8.12. FOS Shimmering Specifications

The unit shall not have any shimmering under any of the following inspection conditions.

Shimmering is defined as moving bands on the front of the screen in the appearance of waterfall, waves, and etc. Shimmering needs to be tested under the following conditions:

- Test Fixture should read Apple approved EDID from panel and drive the panel based on EDID setting
- Pixel Clock Frequency: Apple specified timing
- LED PWM Frequency: Apple specified frequency
- LED PWM Duty Cycle: any duty between 2% to 100%
- Test Image: Full screen R,G,B, White at gray scale 255, 223, 191, 159, 127, 95, 63, 32 and 0 (8 bits)
- Viewing direction: 80deg w.r.t. normal axis in any viewing direction

9. ENVIRONMENTAL

The display modules shall meet all requirements specified herein after testing to the environmental quality standards listed in this section. Additionally, the unit shall meet all the system testing requirements listed in the end of this document.

9.1. Shock Requirements

The unit shall meet all requirements specified herein after exposure to the following shock conditions tested in accordance with MIL-STD-202F Method 213B, test condition A. The unit shall be secured in the test fixture that meets MCO TBD (to be provided by Apple).

- Shock to all 6 sides delivering at least 200 G in a half sine pulse no longer than 2 ms
- Shock of 260 g in a half sine pulse no longer than 2 ms to each of 6 sides. Each of the 6 sides will be shock tested with one each unit, for a total of 6 units
- Shock delivering at least 60 G in a pulse 11 msec or longer

9.2. Sine Vibration Requirements

The unit shall meet all requirements specified herein after exposure to a sine vibration wave of 3.0 G from 5–150 Hz, 0.37 Oct/min for 30 min./axis conducted in accordance with MIL-STD-202F, method 201A. The unit shall be secured in the test fixture that meets MCO TBD (to be provided by Apple).

9.3. Temperature and Humidity

Unless otherwise stated in this specification, the display module must meet functional and cosmetic requirements after testing in accordance with Apple Spec. # 080-0859, non-operating and operating conditions.

For these tests, the following limits set forth in Specification #080-0859 shall be altered to read.

9.4. Non-operational Environmental Requirements

The unit shall perform as specified before and after exposure to the following non-operational environmental conditions.

9.4.1. Low Temperature

-25°C @ 500 hr.

9.4.2. High Temperature

65°C @ 500 hrs

9.4.3. High Temperature and High Humidity

60°C @ 500 hrs, R.H. = 75% ± 10%

9.4.4. Thermal Shock

Cycle display from -25°C to 65°C with 5-minute transfer time,

100 cycles at -25°C/65°C/-25°C.

9.5. Operational Testing

The unit shall perform as specified before and after exposure to the following non-operational environmental conditions.

9.5.1. Low Temperature

0°C for 500 hours

9.5.2. High Temperature

50°C for 500 hours

9.5.3. Heat Soak

65°C and 90% R.H. for 72 hours (no obvious FOS degradation or functional failure)

9.5.4. High Temperature and High Humidity

50°C and 90% R.H. for 240 hours (Functional Check)

Maximum wet-bulb temperature at 39°C or lower without condensation.

9.5.5. Four Corner Test (72 hrs – operating)

40°C @ 10% RH

40°C @ 90% RH

10°C @ 10% RH

10°C @ 90% RH

9.6. Altitude

The unit shall performed as specified herein during and after exposure to the following altitude conditions for 72 hours:

Operational: 15,000 Ft.

Non-Operational: 40,000 Ft.

9.7. Cold Soak

The unit shall be tested at -25 °C for 4 hours.

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Immediately after the panel being taken out of the chamber to room temperature, check the panel uniformity on full white screen at full brightness, every 30 minutes for 2 hours continuously. Repeat the test on the same panel for 5 cycles. There should be no non-uniformity from any viewing angle.

10. FREQUENCY MARGIN

Display shall operate as specified herein and show no FOS performance degradation with $V_{cc} = 4.25V$, refresh rate up to 75 frame/second (Hz). The test should be repeated on the same panel after 72 hours heat soak test (see 7.2.2.3). The change on maximum functioning frame rate should be less than 1%.

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Title: ERIS, DSPL, LCD MODULE, LGD, X34	DWG Number: 069-8326	Rev. B
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11. RELIABILITY

11.1. 4-Corner Peeling Test (Color Filter (CF) & TFT)

The 4-Corner Peeling Test assesses the strength and consistency of the adhesive bond between the two glass layers of LCD unit.

The unit 4-corner peeling test failure load of the 90% Weibull survival rate without polarizer attached shall have a strength no lower than 350 N.

The 4-Corner Peeling test shall be configured as specified below:

- Test panels shall not have polarizer attached
- The Apple approved test fixture shall be configured as shown in Figure 33.

Equipment

- Tensile Load Frame capable of 2kN load
- Load cell with load capacity between 1kN and 2kN
- Apple fixture parts (CAD will be provided)
 - Upper bracket
 - Lower bracket
 - Pin
 - Base
- Bondit B45TH Epoxy (McMaster P/N 7513A1)
- Glass panel samples

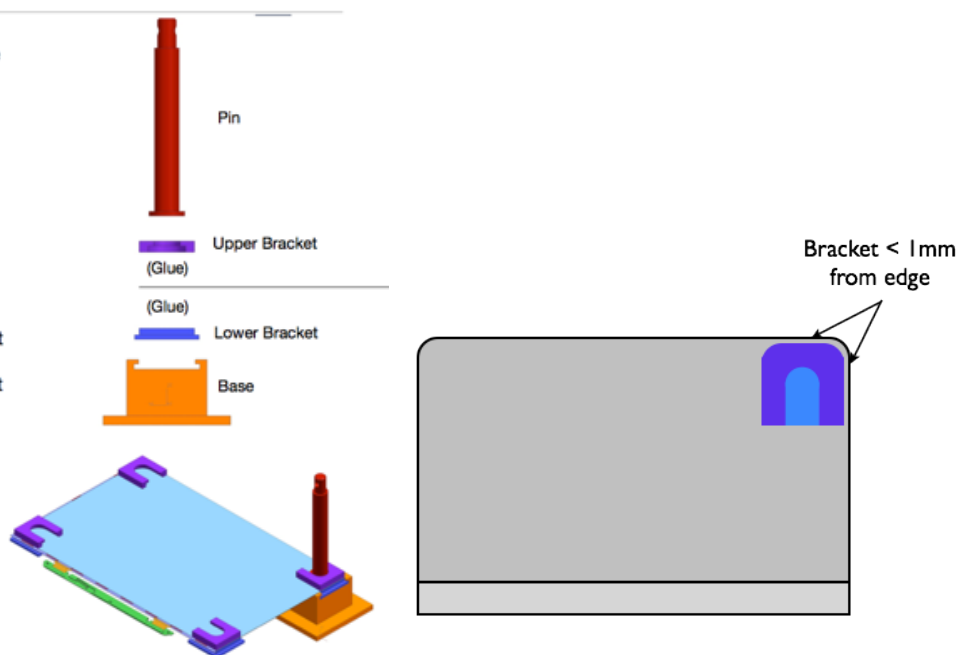


Figure 33 4-Corner Peel Test Setup

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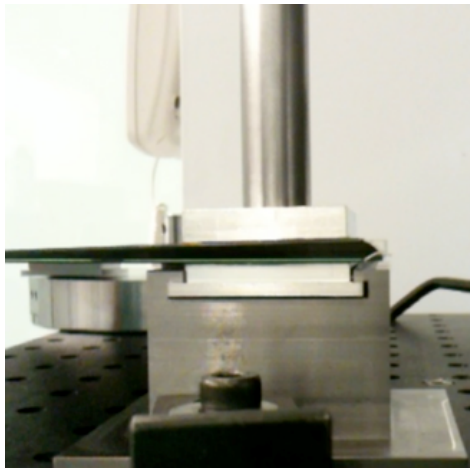


Figure 34 4-Corner Peel Test Example

11.1.1. 4-Corner Peel Test Procedure

- The panel shall be inspected to confirm sealing width meets specified requirements
- A very thin epoxy should be spread uniformly over the contact area. The epoxy cannot flow past the bracket edges and onto the glass edge or to the exposed surface of the bracket.
- Press brackets (2) firmly onto glass on opposing corners. Epoxy must be allowed to cure 24 hr prior to testing
- Verify brackets should be placed within 1 mm of each edge as shown in Figure 33
- The peel tester speed shall be set to 5 mm/min
- The loading curve shall be recorded with maximum peeling force occurred at the CF & TFT separation
- Data Collection:
 - Table containing peak load and S/N
 - Raw data in .csv format provided with time, position and load column
 - Photo of setup and video of a single run
 - Photos of failure modes and document the de-lamination initiation sites
 - Repeat the test for a minimum of 30 modules (2 test points per module)

11.2. LCD Assembly Ball-on-Ring Test

This test applies a load to a sample via a ring and a ball under uniaxial loading. The primary purpose of this test is to measure the equibiaxial strength of a sheet of brittle material without the influence of strength limiting defects that may be present at the edge of the sheet.

The unit failure load of the 90% Weibull survival rate shall be no less than the values specified below:

TFT Up: 50 N

CF Up: 100 N

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The Ball on Ring strength (failure load) is defined at the single 90% survival rate value on Weibull probability plot as shown in Figure 115.

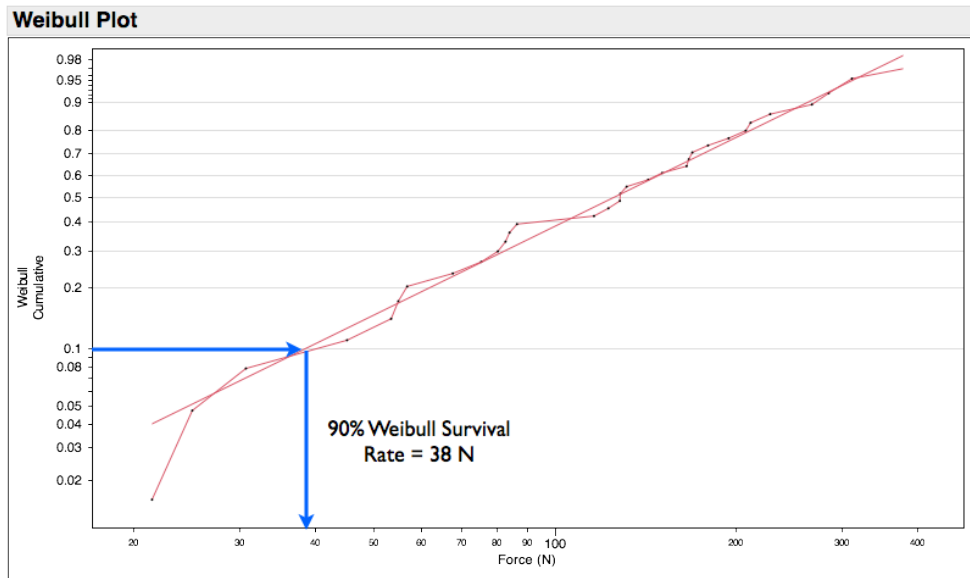


Figure 115 BOR 90% Survival Rate on Weibull Probability Plot

11.2.1. BOR Test Configuration

The test fixture shall be secured in a test fixture that meets the following requirements and summarized in Figure 35:

- Ball Diameter: 127 mm
- Ring Diameter: 70 mm

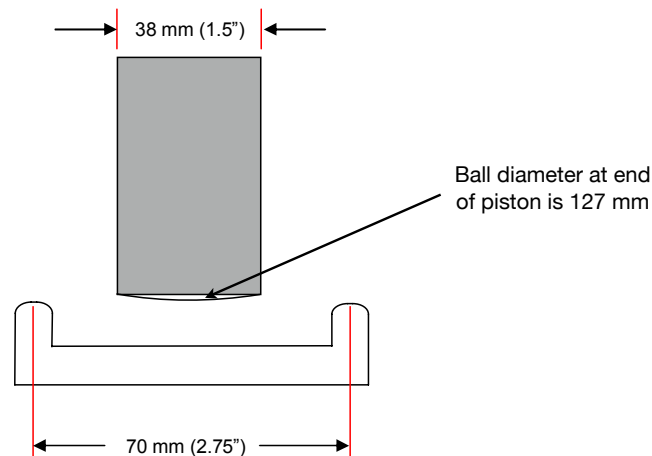


Figure 35 Ball and Support Ring Geometry

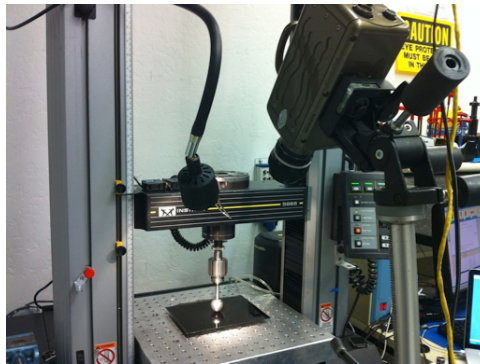


Figure 36 Example of Ball on Ring Test Configuration (Instron)

11.2.2. BOR Test Procedure

- The LCD glass cell assembly shall be placed in between the load and support ring at the center of the LCD cell assembly.
- The TFT glass side shall be facing the ball.
- The test shall be conducted with the top load ball velocity of 5 mm/min.
- As soon as the first local loading peak/break occurs, the test shall be stopped.
- Record the following data for the failed sample:
 - Maximum force (N)
 - Displacement (mm) at time of fracture
 - Image of failed sample
 - Repeat the test 5 times at each location specified in Figure 37 for a total sample size of 45 units.
 - Ball distance to edge of module shall be $> 40\text{mm}$
 - Process in Weibull diagram

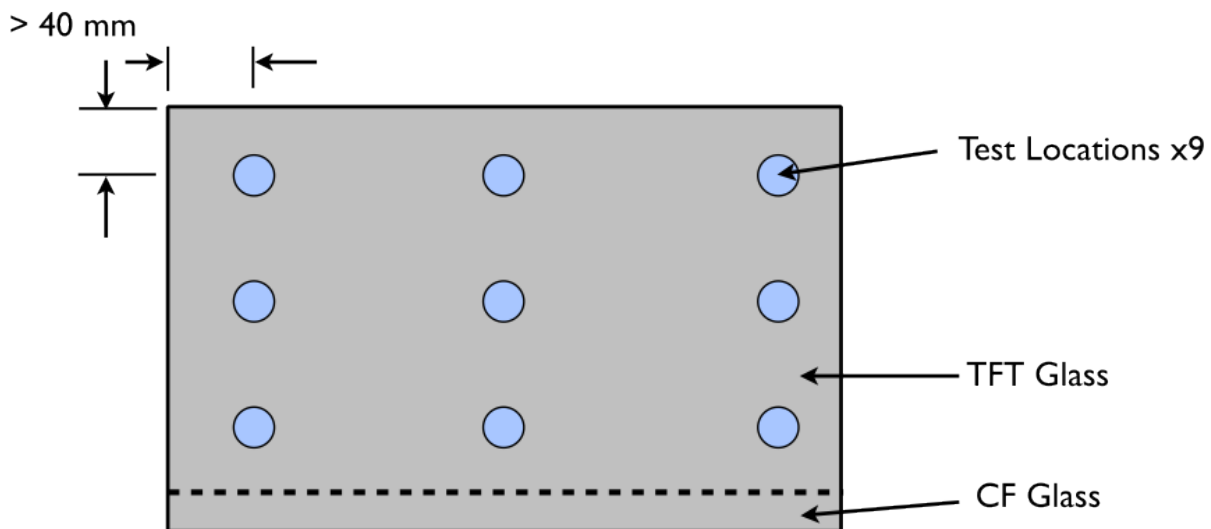


Figure 37 Module Test Locations for Ball on Ring Test

11.3. LCD Assembly 4-Point Bend Test

The unit 4-Point Bend failure load of the 90% Weibull survival rate on both the TFT and CF sides without polarizer attached shall have a strength no lower than 120 MPa with a design goal of 150 MPa.

The 4-Point Bend strength (failure load) is defined at the single 90% survival rate value on Weibull probability plot as shown in Figure 38.

The failure stress shall be calculated using the 4-Point bend equation with a correction factor as shown below:

$$\text{4-Point Bend Equation: } \sigma = k * \frac{3P(L_2 - L_1)}{2bh^2}, \text{ where } k = 1.65$$

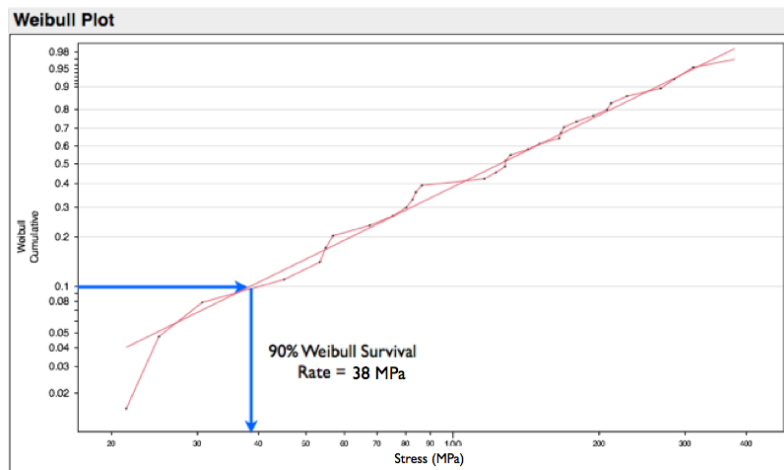


Figure 38 4 Point Bend 90% Survival Rate on Weibull Probability Plot

11.3.1. 4-Point Bend Test Setup

The detailed fixture design/ shall follow the ASTM standard C158-02. The fixture is used in conduction with a load-displacement machine, commonly known as Instron. The test setup and glass configuration are shown in Figure 39, Figure 40, and Figure 41.

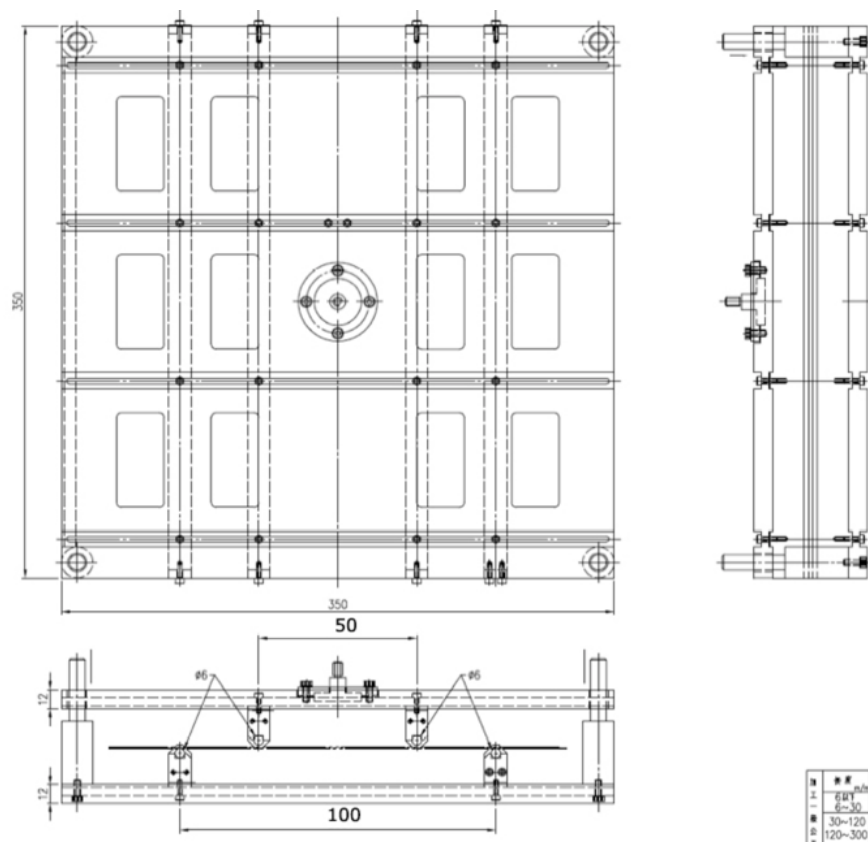


Figure 394 Point Bend Test Setup

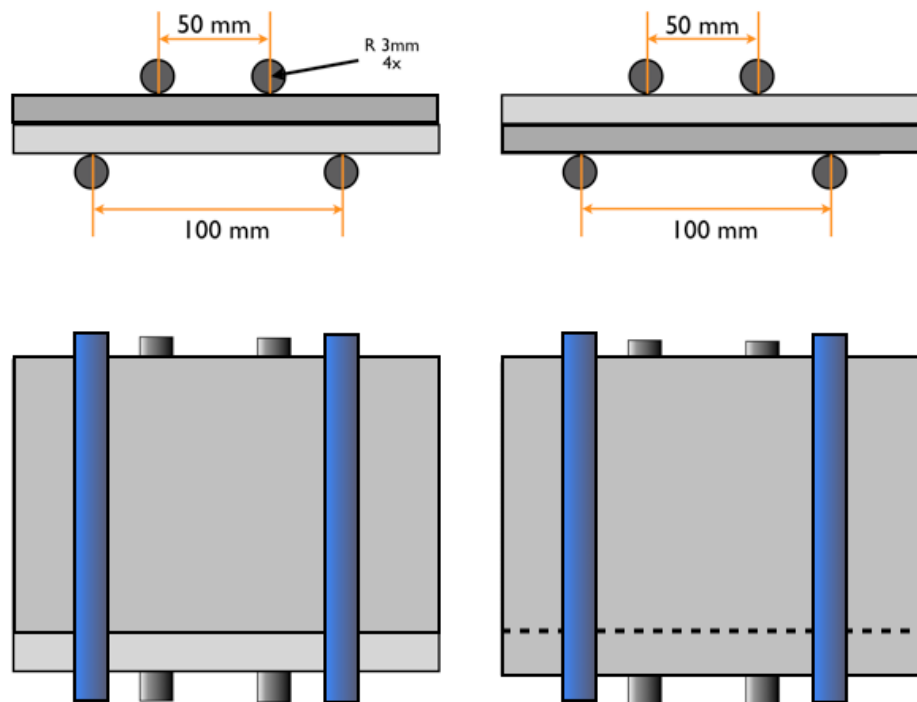


Figure 40 4-Point Bend Horizontal Glass Configuration

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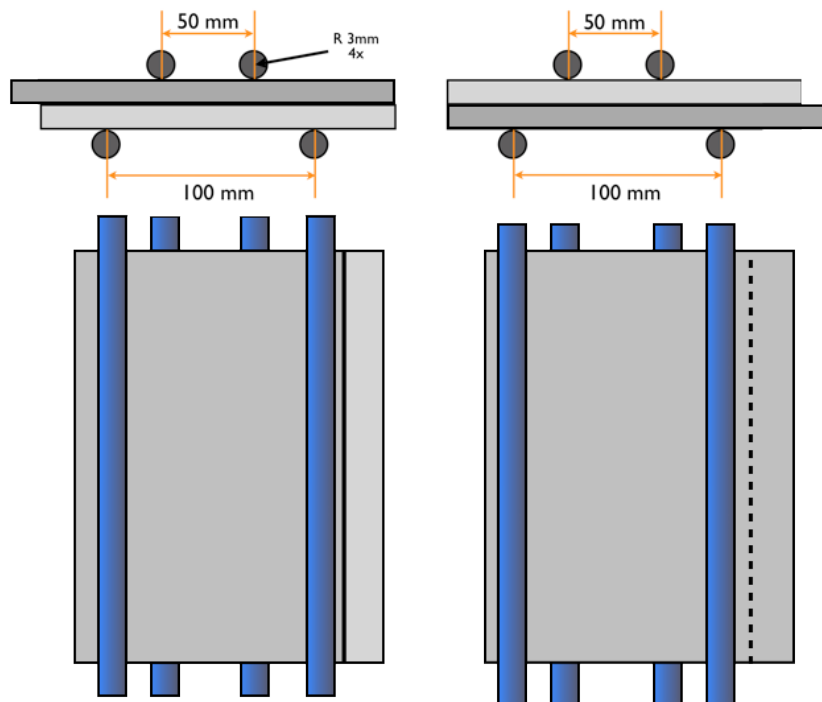


Figure 41 4-Point Bend Vertical Glass Configuration

11.3.2. 4-Point Bend Test Procedure

The LCD unit shall be placed in centered in the 4-Point Bend test fixture

The testing shall have a minimum sample size of 30 in the horizontal configuration (Figure 40) and 30 in the vertical configuration (Figure 41) with 15 samples with TFT glass facing up and 15 samples with the Color Filter facing up.

- The test shall be conducted with the top roller velocity of 5 mm/min.
- As soon as the first local loading peak/break occurs, the test shall be stopped.
- Record the following data for the failed sample:
 - Maximum force (N)
 - Displacement (mm) at time of fracture
 - Image of failed sample
 - Failure initiation site (as shown below)

11.3.2.1. Failure Initiation Site

Failure initiation site must be determined by visual inspection by selecting one of the different cases shown below and in Figure 1113.

Case A) If the failure is starting from the bottom edge or close to it

Case B) If the failure is starting from the top edge or close to it

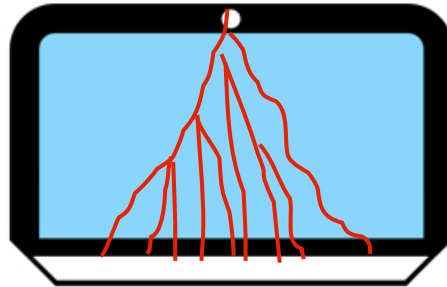
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Case C) If the failure is starting from the surface of glass, away from the edges and showing branching in both directions

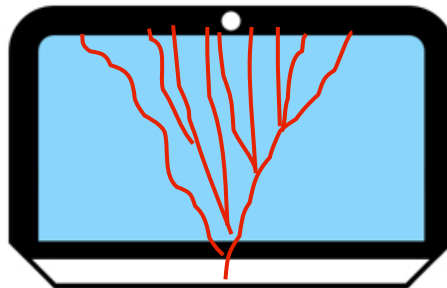
Case D) When testing in orientation D (Figure 1.D), if the failure is starting at the epoxy region between the panes, enter letter C edges of the glass (case D).

Case E) If during testing a snap is heard, but no crack is visible, enter letter E

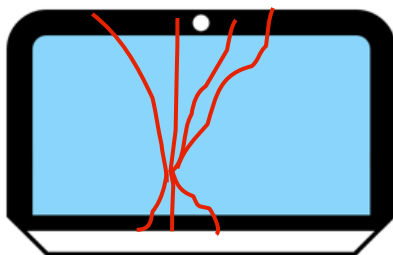
Case O) If the failure does not match any of the above or cannot be easily recognized due to catastrophic breakage, enter letter O.



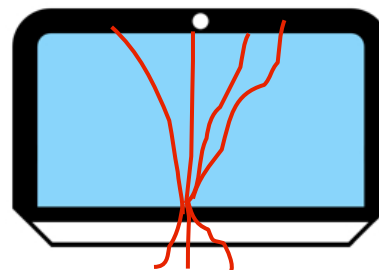
Type A. Failure from top edge (camera hole region) with or without slight branching near edge



Type B. Failure from bottom edge (TFT ledge region) with or without slight branching near edge



Case C. Initiation on surface of glass



Case D. Failure at surface on epoxy region

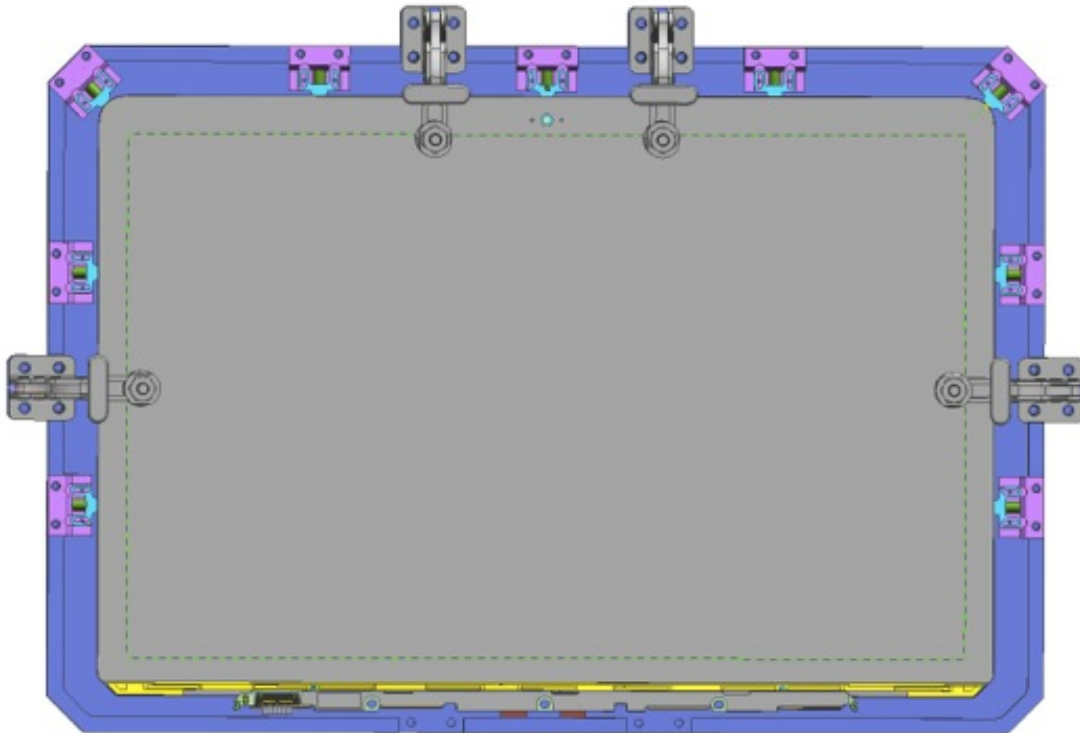
Figure 42 4-Point Bend Failure Case Overview

11.4. Polarizer Perimeter Delamination Test

The unit shall meet all specified requirements herein after exposure to the following polarizer edge delamination testing.

Test Procedure:

- The panel shall be inspected to record size and location of all polarizer bubbles at the interface locations
- The LCD module shall be loaded into the delamination test fixture with the CF side up.
- The glass support pins and polarizer delamination pins shall be engaged.
- The unit shall be tested at the heat soak conditions at 65°C and 90% R.H. for 72 hours
- The polarizer interface and polarizer bubble shall be inspected and compared to the original condition
- The testing shall be performed on a minimum of 10 LCD modules.



11.5. LCD Display Column Spacer Test

The unit shall meet all specified requirements herein after exposure to the following backpack testing:

Failure mode is gray spots (internal damage)

Frequency / cycles / force

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Location / test fixture / test fixture geometry

11.6. Flexible Printed Circuit (FPC) Strain Relief

FPC strain relief glue shall be applied on the joint of the rigid flex and TFT glass as shown in Figure 43 to prevent trace crack due to FPC fatigue.

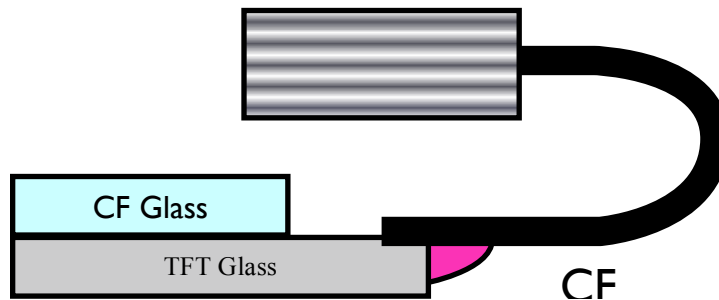


Figure 43 Strain Relief on the FPC

11.7. Rigid Flex Bending Tests

The unit PCB rigid flex shall survive the following flex over mandrel bending test. The display must survive a minimum of 20 cycles but tested up to 50 cycles. The flex is tested at bare flex level. The FPC bend test must be done using Apple-approved bend fixture.

Bare FPC-level testing:

- Room temperature 25 deg C: 10 samples each bend for 50 cycles
- Heat Soak: After the 65 deg C/ 90% RH (Heat Soak) conditions. 10 samples each bend for 50 cycles.
- Thermal Shocking: After -25 °C ~ 65 °C(5min transfer time), 100cycle (Apple Thermal Shocking) condition. 10 samples each bend for 50 cycles.

Test Procedures

- Before any bending occurs, inspect the flex under 30X minimum magnification to look for cracks in the traces and tears in the flex. Check for electrical continuity by either a functional test or multimeter.
- Bend the flex over itself using mandrel whose diameter is 0.6 mm (2-3x flex thickness). See Figure below. The flex shall follow the outer diameter of the mandrel during the 180 deg bending.
- After 10 times inspect trace under 30X minimum magnification to look for cracks in the traces and tears in the flex. Check for electrical continuity by either a functional test or multimeter.
- Continue testing till failure or 50 cycles

Pass Criteria

- No loss of continuity of the flex
- No visible cracking/ tearing

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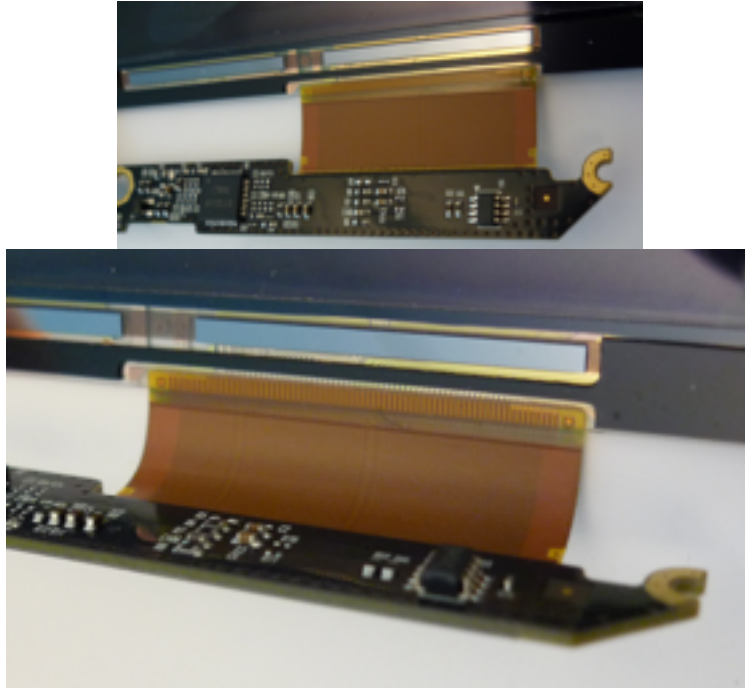


Figure 44 FPC Level Bending Test

11.8. Flex Cable to Glass Bonding Strength

Static Peel Strength Test for FPCB & Glass Bonding shall have a minimum pull force of 500 g/cm and a minimum average of 800 g/cm (32 samples min) to the module sample.

$$\text{PullForce} = \frac{\text{Applied Total Force [lbs.]}}{\text{Heatseal Bond Width [in.]}}$$

Force direction should be perpendicular to the glass-viewing plane. The total force should be spread over the entire heat seal area. After pull sequence, check sample functionally for missing pixels and LCD operation. Test pattern should be normal and inverse checkerboard to test functionality of all pixels. Record any total or partial bond failures or display pixel failures. Any failure in display module function indicates failure for the sample.

11.9. Spacer Rigidity Testing

The unit spacer hardness shall be tested at the processed CF glass level.

The average t0 to t1 modulus curve shall be equal or higher slope than the attached curve below. The t2 to t3 curve shall be within 0.03 um comparing to the t1 to t0 curve.

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Test Procedures:

- Equipment: Fischerscope HM2000
- Load: 50 mN
- Speed: 2.5 mN/ sec
- Holding Time: 5 sec
- Tip Radius 50 μm



Figure 45 Fischerscope HM2000

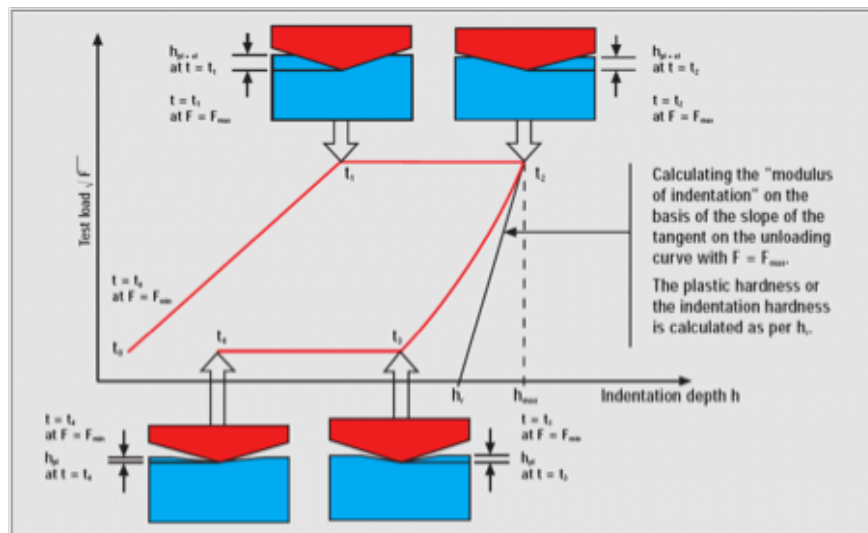


Figure 46 Spacer Rigidity Test

11.10. Shielding ITO Sheet Resistance Heat Soak

The sheet resistance of the shielding ITO layer on top of color filter glass shall perform as specified herein after 500 hours test at 60°C and 90% R.H.

The test shall be performed at the module level with polarizer laminated to the ITO surface.

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11.11. Electrostatic Discharge (ESD) Test

Display modules are to be tested for. The LCD module shall meet the ESD susceptibility Level 1 test requirements as specified per Apple specification 062-0302

The unit shall be assembled in the backlight test fixture.

11.12. MTBF

Supplier to demonstrate display module meets minimum 50,000 Hrs.@90% Confidence
Supplier to include any acceleration factors included in the calculations. Power cycling frequency during this test is to be approved by Apple.

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Title: ERIS, DSPL, LCD MODULE, LGD, X34	DWG Number: 069-8326	Rev. B
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12. COSMETIC REQUIREMENTS

The LCD module must meet Apple Cosmetic Specification over the entire viewing cone. X34 Unified LCD Board Assembly Cosmetic Specification, 069-7366

13. DISPLAY SERIAL NUMBERS AND LABELING

The unit shall have a label permanently affixed with permanent, scannable and legible print that will not deteriorate in the environmental conditions specified herein. An Apple serial code as specified in Table 12, a corresponding 2-D bar code, and a display module build code need to be printed clearly on the label as specified in 069-7821 LCD, MCO, X34

Table 12 Apple Development Display Label Requirements

	*	KL	8	06	MTCB	7DL	A	*
Explanations	Bar Code Start Character	Plant or Vendor Code	Year of Manufacture	Calendar Work Week	Serial number (base 34)	Apple assigned EEE#	Engineering Revision	Bar Code Stop Character
Examples						5RW	0 for engineering samples, A, B,... for MP rev	

14. REGULATORY

14.1. Product Safety (Environmental, Ergonomics, Safety and Health)

Materials: The vendor is to provide Apple, upon request, specific chemical composition information or certifications necessary for the product to enter countries, markets, and/or for component(s) material identification, or for Apple to respond to customer requests for information. The information may be in the form of, but is not limited to, Material Safety Data Sheets, material specification sheets, health hazard information, certifications, or other forms of documentation.

14.2. RoHS Compliance and other Substance Regulations

This product's components, parts, and packaging shall be manufactured or assembled based upon the following requirements.

The display module must comply with the European RoHS directive, 2002/95/EC and the Apple RoHS Compliance Specification, 069-1111. As evidence of such compliance, the supplier must provide Apple a declaration of conformity in accordance with Apple's RoHS Declaration of Conformity Procedure, 080-2153.

In addition to RoHS compliance, the display module and its manufacturing process shall comply with Apple's Regulated Substances Specification, 069-0135.

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The vendor shall provide a written statement declaring the average and maximum amount of mercury in the display module.

14.3. Halogen Free

The unit shall be halogen-free in accordance with the Apple Halogen-Free Specification, 069-1857

14.4. Environmental Markings and Recycling

The unit shall be modular in design so that parts can be easily separated, without any special tools, for ease of proper recycling/disposal at the product's end-of-life.

Any plastic parts >25 grams in the unit shall be marked according to ISO 11469 with the exception of the following components: LGP (light guide panel) and optical films in the backlight.

14.5. Product Safety

Flat panel display assembly shall comply with Apple Specification, 069-0279, Product Safety Requirements for Component Flat Panel Display Assemblies.

14.6. Ergonomics

The flat panel display must comply with the ergonomic requirements of ISO 13406 parts 1 and 2. The vendor shall provide a written statement that the flat panel display, supplied to Apple, is certified to comply with ISO 13406, parts 1 and 2.

14.7. Electromagnetic Compatibility (EMC)

14.7.1. Electromagnetic Emissions Requirements

The unit shall meet Apple Class B Emission Standards for home electronic device when configured within a system per Apple Spec. #062-7993. The display supplier must provide all necessary support as required to meet this requirement. EMI measurements are taken at the worst-case contrast setting.

14.7.2. Electromagnetic Immunity Requirements

Performance degradation due to external noise or RF will be considered as specified in #062-7994 for Class B products.

14.7.3. EMC Production Audit Procedure

Supplier shall follow Apple Spec 080-840 to conduct EMC production audit.

15. Acronyms

Place list of acronyms here: